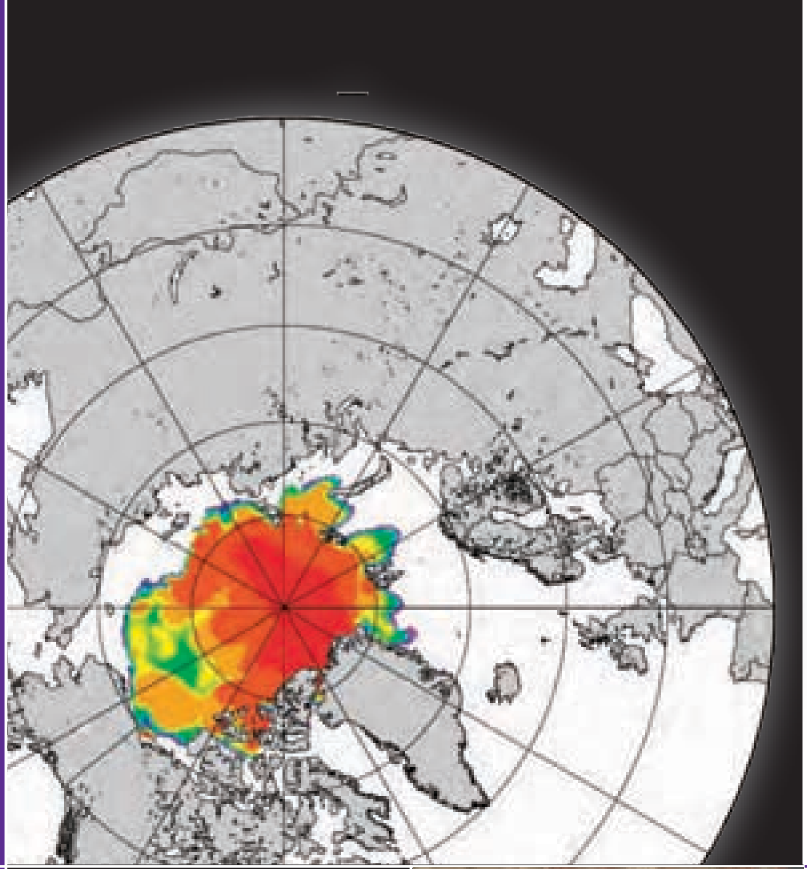

High Performance Computing Modernization Program

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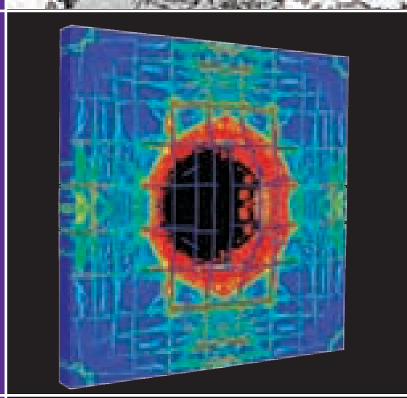

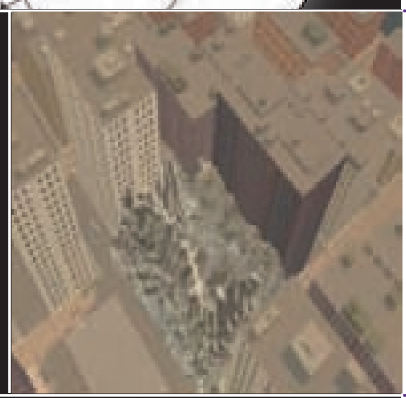

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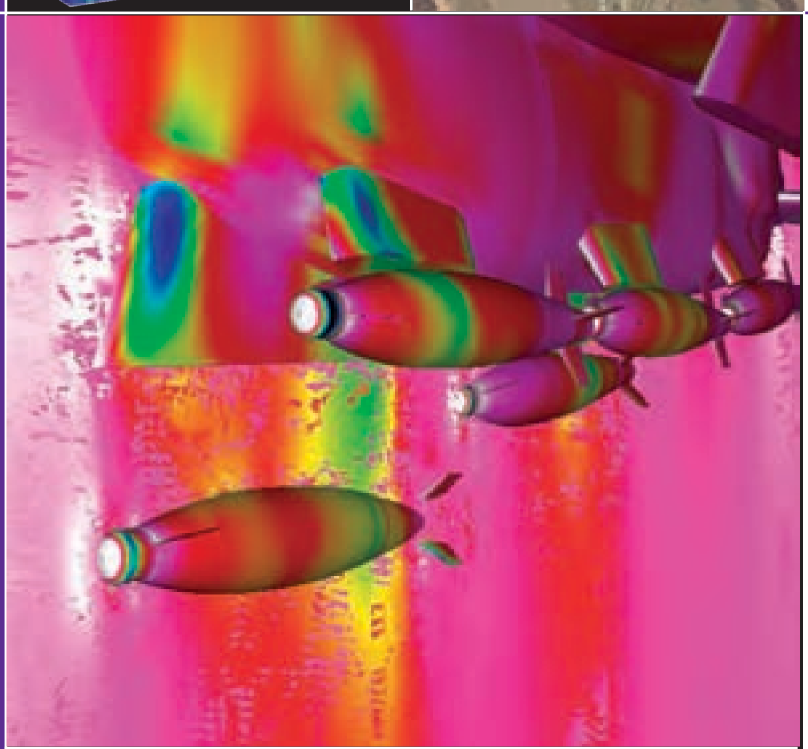

Tools for Discovery

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Department of Defense

High Performance Computing Modernization Program

2006 Annual Report

A report by the Department of Defense
High Performance Computing Modernization Program Office

March 2007

Message from the Director

The High Performance Computing Modernization Program (HPCMP) continues to deliver to the Department of Defense (DoD) one of the world's top supercomputing infrastructures. By the end of 2006, the program had eight of the world's largest supercomputers deployed at four Major Shared Resource Centers (MSRCs). (In terms of raw computing capacity the Program is the second largest acknowledged program in the world.) Today, the Department of Defense has access to some of the world's most powerful supercomputers and to a variety of computing architectures, chosen to best meet the Department's identified requirements. This allows our scientists and engineers to match software applications to supercomputers. Our Defense Research and Engineering Network provides connections to over 150 sites with connection speeds ranging from 45 to 2,400 megabits per second.

Perhaps, most importantly, our program provides key computer and computational science expertise to scientists and engineers across the Department. We successfully completed several software development projects that introduced parallel, scalable production software now in use across the Department and the broader national community. This past year, we delivered 55 training events, attended by 802 people and coordinated technology sharing projects between the defense laboratories and over two dozen universities.

These activities and the daily work performed by members of the HPCMP community have a positive impact on our national defense posture. Our scientists and engineers are now in possession of tools once only imagined. They are developing and deploying weather and ocean models that allow our soldiers, sailors, marines and airmen to plan missions more effectively and to navigate adverse environments safely. They are modeling molecular interactions leading to the development of higher energy fuels, munitions, and materials enabling cheaper, more environmentally friendly access to space, more effective weapons, and stronger and longer lasting materials. They are modeling structural responses to different blast environments, guiding improved force protection programs, and designing new guidelines for buildings and structures. Today, we support over 550 individual projects—research, advanced development and applied engineering, test and evaluation—each contributing to our national defense posture.

As the program completes another year, we continue to improve the Department's supercomputing environment supported by leading edge networking capabilities. The DoD HPCMP community is working in concert with other federal agencies to identify future trends and requirements.

While the state of commercial computing hardware continues to advance at a rapid pace, driven by a huge commercial market and Defense Advanced Research Projects Agency (DARPA) investments, advances in parallel software driven primarily by federal investment have not kept pace with the hardware. We are planning an initiative to focus on high performance software (which we call Computational Research

and Engineering Acquisition Tools and Environments — CREATE), to take advantage of DARPA's High Productivity Computing Systems (HPCS) program. The budget for CREATE was included in the President's 2008 Budget.

CREATE will begin to deliver enhanced engineering design tools within 3 to 4 years after the projects begin. Fully mature tools will be delivered at the end of a 12-year project schedule.

The community is now developing a plan for realizing the CREATE program. That plan is based on the "lessons learned" from similar scale projects carried out by the nuclear weapons, the climate modelling, and other computational communities. It builds on the DoD experience with our institutes and portfolios as well. The CREATE 12-year budget is about $350M with a 70% contribution from Office of the Secretary of Defense and a 30% matching contribution from the services. The tri-service T&E communities will provide validation experiments and data for the projects as well.

Our Department's needs for science and engineering to speed its Transformation Goals continue to accelerate. The High Performance Computing Modernization Program team is dedicated to deploying and operating superior supercomputing environments and productivity enhancing services allowing DoD's scientists and engineers to develop the best technological solutions for our nation's defense. As President Bush has said, "science and technology have never been more essential to the defense of the nation..."

Cray J. Henry
Director
High Performance Computing Modernization Program

Acknowledgements

Many professional colleagues in the field and in the program office – far too many to acknowledge in this brief section – have contributed to this annual report. I thank them for their assistance and enthusiastic support. All the efforts described in this document were performed using resources provided by the Department of Defense High Performance Computing Modernization Program. Additional sponsorship has come from the Offices of Research, the Defense Laboratories, and the Test and Evaluation Centers.

Clifford E. Rhoades, Jr.
High Performance Computing Modernization Program

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Section 1
HPCMP Overview

Introduction

Today, the Department of Defense (DoD) faces many challenges. We must defend America by maintaining a military second to none. And we must do so affordably.

The High Performance Computing Modernization Program (HPCMP) provides some of the tools the Department needs to address defense problems. These tools include modern high performance computing hardware and software and the expertise to use them.

Our military strength depends on many factors. Our people are our greatest asset for they are our intellectual capital. They include active service members, Reserves, National Guard, civil servants, political appointees, and contractors. High performance computing (HPC) hardware and software help our people make our military the best in the world.

Many military problems are complicated and often require very powerful tools to be solved. Some problems are too expensive for experiment to address. Others are too difficult to be solved with paper and pencil. The Department uses high performance computing tools to help solve some of these hard problems. These hardware and software tools give us advantage over potential adversaries that don't have them.

Many modern weapons systems present hard problems. Early in system development, we must make trade-offs to balance performance, time and available resources. How do we determine cost, schedule and performance? How do we take into account technical and management risks? HPC hardware and software contribute to answering these questions.

HPC hardware and software help us answer other important questions as well. They can be used to address a wide spectrum of issues, including: protecting our bases of operations through the mitigation of toxic threats; modeling to support certification of new aircraft-store combinations before deployment to conflicts in Afghanistan and Iraq; supporting US supremacy in space; conducting climate, weather, and ocean modeling that provides valuable information for countermine warfare operations; preparation for emergency operations and humanitarian relief operations throughout the world. These are but a few examples.

Over a decade, the HPCMP has supported a workforce that routinely uses HPC resources to solve many of the Department's most challenging

HPCMP Mission

Accelerate development and transition of advanced Defense technologies into superior war fighting capabilities by exploiting and strengthening US leadership in supercomputing, communications, and computational modeling.

HPCMP Vision

A pervasive culture existing among DoD's scientists and engineers where they routinely use advanced computational environments to solve the most demanding problems.

scientific and engineering problems. This, in turn, helps the United States ensure military advantage and war-fighting superiority on the 21st century battlefield.

The Program enables scientists and engineers to further the Department's objectives through research, development, test, and evaluation (RDT&E) activities that support science and technology (S&T), and test and evaluation (T&E). These endeavors focus on the most complex, and highest priority defense challenges. This annual report highlights a small portion of the work being done to support the Department's Transformation Goals. Defense scientists and engineers, using resources provided by the HPCMP, address multi-disciplinary scientific and engineering challenges. These include problems of interest across the services and to joint force commanders. Improving the accuracy of ocean and weather prediction models, designing materials for specific purposes such as body armor or agile laser eye protection, and modeling complex flow fields around air systems to increase performance are examples. Today's work will:

- improve detection of targets based on their spectral or spatial/spectral signatures;
- advance dynamic signal intelligence mission planning;
- enhance force protection against terrorist threats; and
- address the critical need to develop new high energy density materials for explosives and rocket fuels.

Congressional investments in and support of the HPCMP since fiscal year 1994 have caused cultural changes in the fundamental way S&T and T&E are pursued. In 1993, the Department had just over 180 gigaFLOPS (10^9 FLoating-point OPerations per Second) (or GF) of computational power to support the S&T community. By the end of 2006, the program had over 315.5 teraFLOPS [10^3 gigaFLOPS] of computing capacity, a factor of over 1,750 improvement!

Figure 1 illustrates the growth in computational capabilities just at our High Performance Computing Resource Centers. This vast increase in capability was obtained by applying sound management practices and good investment strategies. Similarly, we transitioned our communications network linking the laboratories from a government-owned, government-operated asset to a commercial environment with secure, high bandwidth capability.

The HPCMP achieves the Program's mission and vision (as described on pages 5 and 6) by focusing on five specific goals. Each activity within the program supports one or more of these goals, with progress tracked and successes delineated. These five goals are:

- acquire, deploy, operate and maintain best-value supercomputers;
- acquire, develop, deploy and support software applications and computational work environments that enable critical DoD research, development and test challenges to be analyzed and solved;
- acquire, deploy, operate and maintain a communications network that enables effective access to supercomputers and to distributed S&T/T&E computing environments;

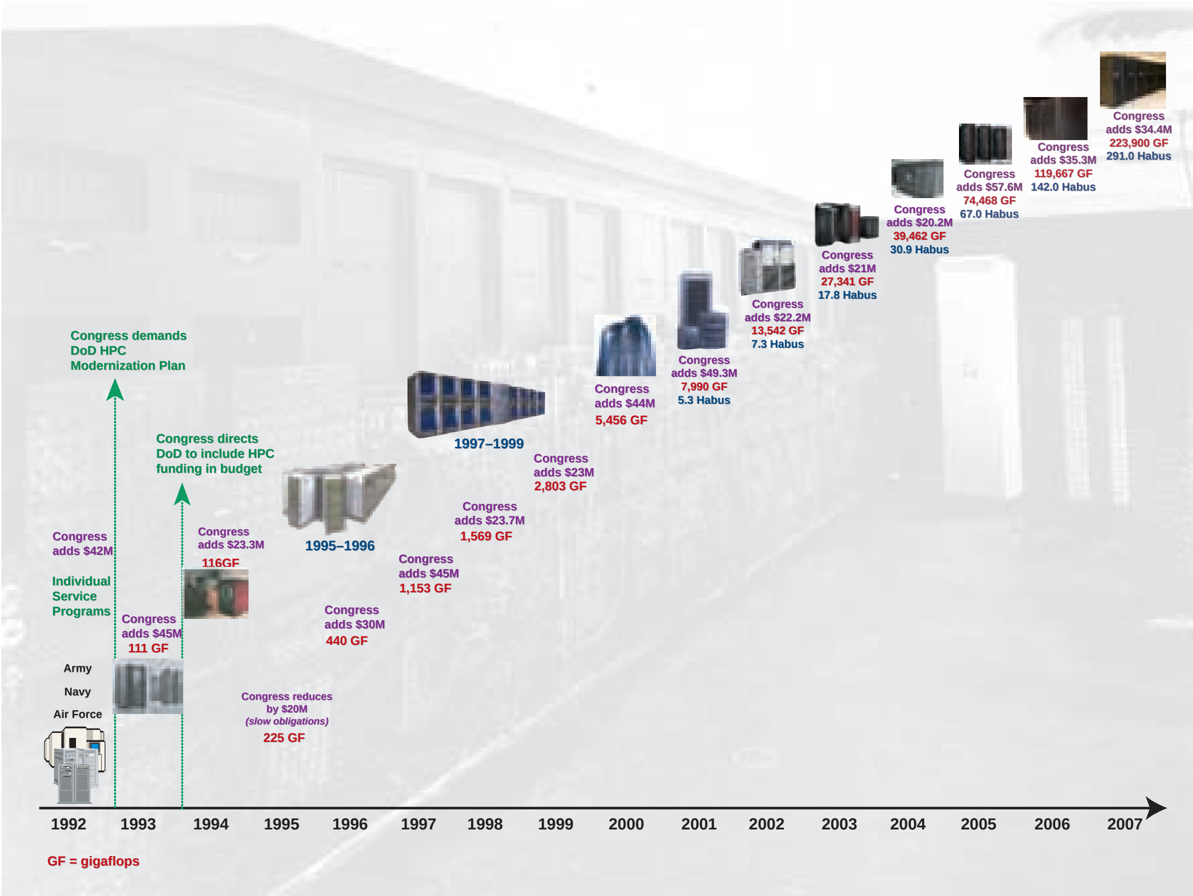


Figure 1. Computational capability at the Major Shared Resource Centers at the beginning of the fiscal year

- promote collaborative relationships among the DoD computational science community, the national computational science community and minority serving institutions; and
- continuously educate the research, development, test, and evaluation workforce with the knowledge needed to employ computational modeling effectively and efficiently.

The progress the HPCMP has made in meeting these goals is discussed in detail later in Section 2.

The HPCMP Community

The HPCMP community consists of nearly 4,000 scientists, engineers, computer specialists, networking specialists, and security experts working throughout the United States. All three Military Departments and several Defense Agencies participate in the program. These users execute over 500 projects—each validated by the Military Services and Defense Agencies. Figure 2 shows the locations of people using the program's resources. The user base is diverse, drawing from the government workforce, academia, and industry. The demographics by type of workforce as well as by the DoD organizations are shown in Figure 3. Most work, done by the HPCMP community, is in one or more of the program's ten computational technology areas (CTAs) (see Table 1 on page 10). Figure 4 includes a breakdown of users by CTA.

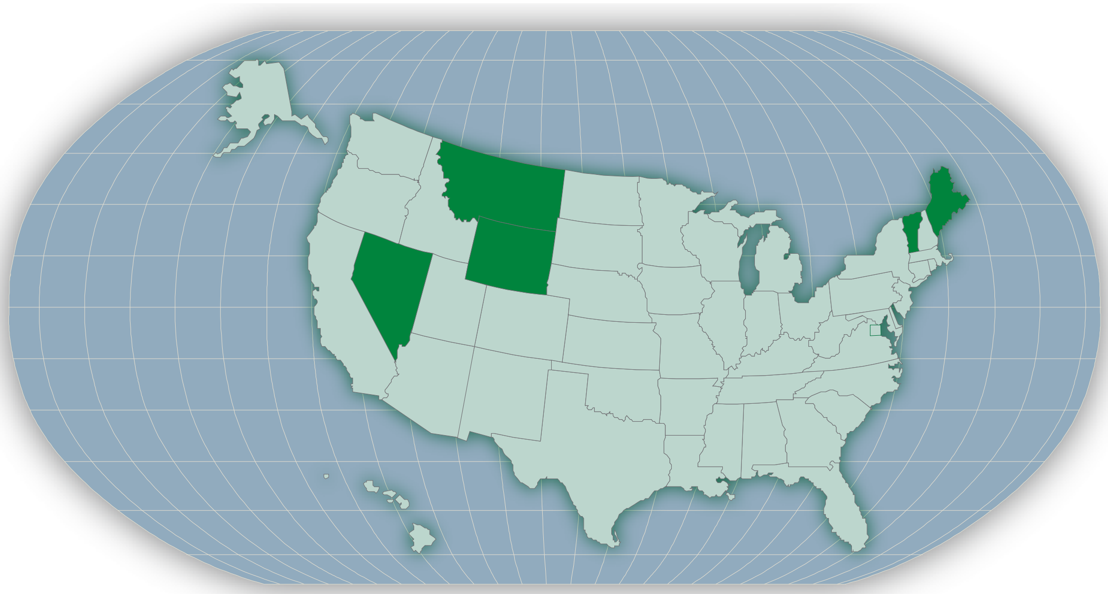


Figure 2. The light green color represents states with people using HPCMP resources

HPCMP Community Computational Requirements

Validated requirements serve as the basis for HPCMP investments and operational decisions. Each year, the program gathers, assesses, and validates user community requirements. This requirements determination includes all aspects of HPCMP activities and capabilities: system hardware, software, networking, and training. In the past year, overall requirements increased and are projected to continue to increase at a steady, consistent rate. Total requirements in any given year are approximately two and one-half times total program capability, ramping up from approximately 540 teraFLOPS or 310 Habus in FY 2007 to 1,752 teraFLOPS or 2,190 Habus in FY 2011 (see Figure 5). [Habus are a measure of computational performance. See callout on page 11 for a definition.] Once collected, the Services' and Agencies' S&T and T&E Executives review, correct, validate, and approve their requirements. HPCMP conducts requirements analyses as a fundamental part of an overall systems engineering process that collects and analyzes information to make investment decisions.

The general conclusion of that requirements analysis is that a complete HPC environment must be provided to support the DoD's S&T and T&E communities. A spectrum of computational platforms, both at the unclassified and classified levels, must be provided so that a wide range of DoD applications may be efficiently supported. These platforms must be balanced with respect to computational power, central memory, and file storage capabilities. A variety of systems and applications software that enable DoD computational scientists and engineers to perform their mission are required. A reliable high-speed network that connects the users to these resources and to each other is required, as is the continuation of an aggressive training program that broadens and educates DoD's HPC users. Progress must be balanced across all program activities to optimize the impact of HPC on the DoD S&T and T&E programs' support of the war fighting mission.

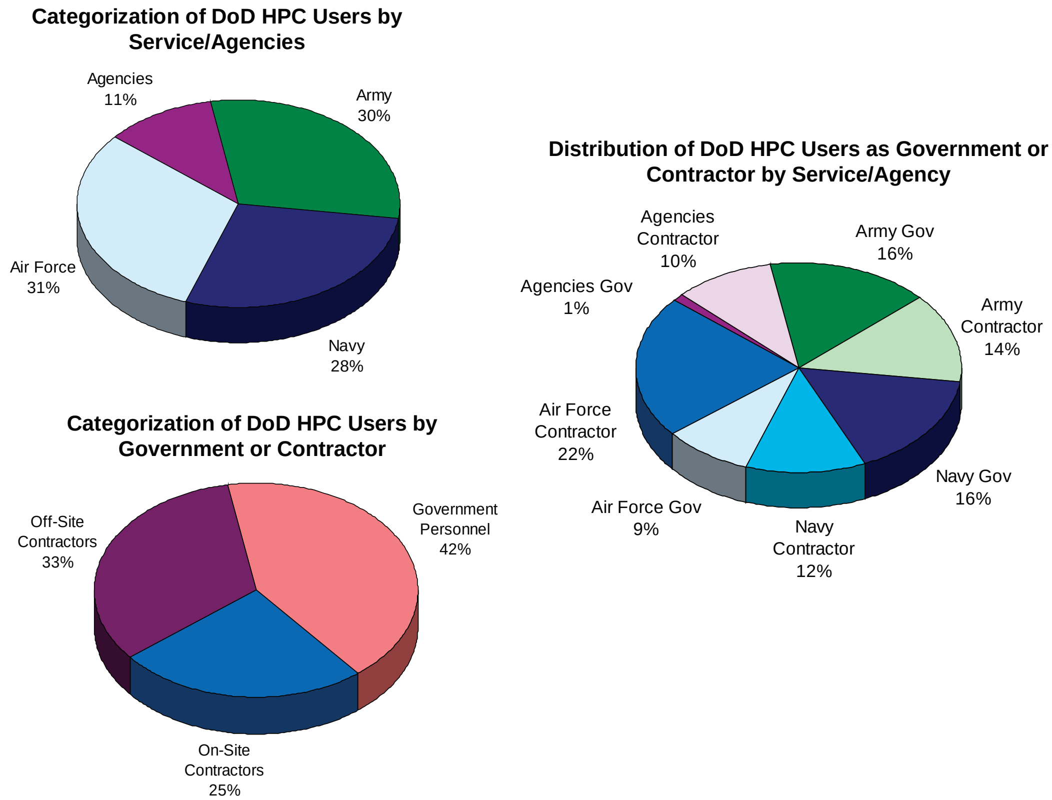


Figure 3. FY 2006 HPC user demographics

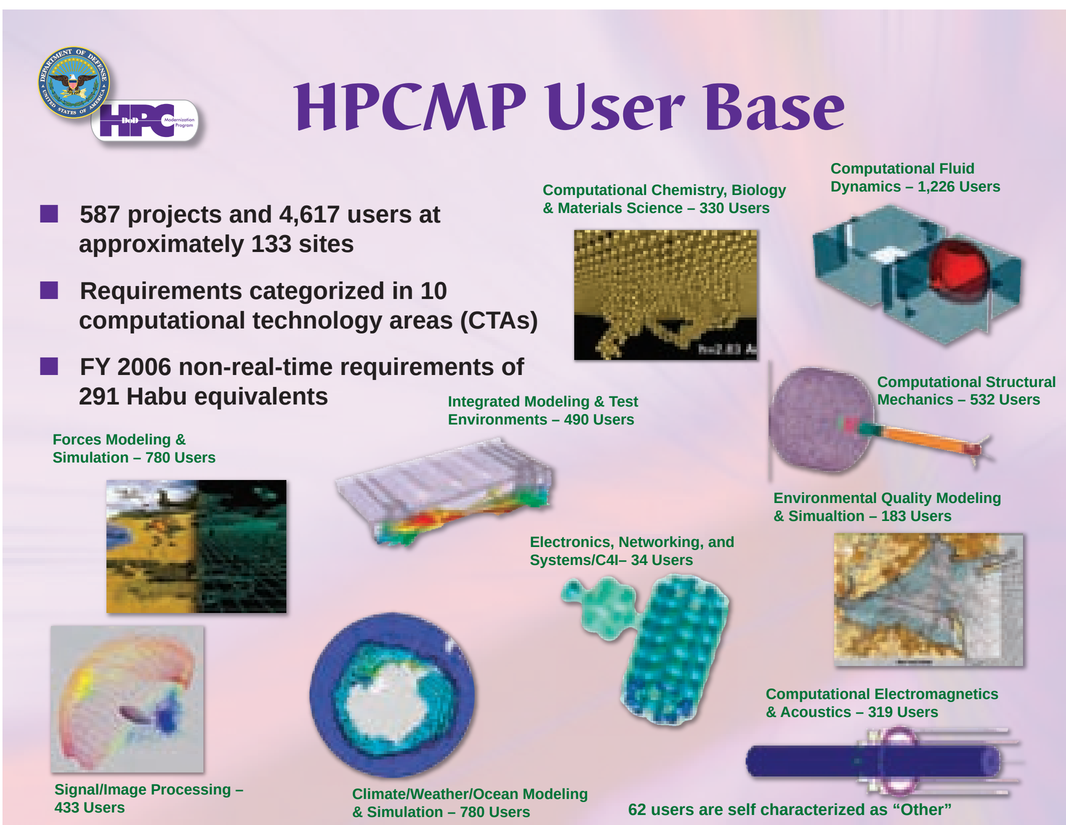


Figure 4. HPCMP serves a large, diverse, Department of Defense, user community

Table 1. Computational Technology Areas (CTAs)

Computational Technology Area	Acronym	Description
Computational Structural Mechanics	CSM	Covers the high resolution, multi-dimensional modeling of materials and structures subjected to a broad range of loading conditions such as quasi-static, dynamic, electro-magnetic, shock, penetration, and blast.
Computational Fluid Dynamics	CFD	Provides accurate numerical solution of the equations describing fluid and gas motion.
Computational Chemistry, Biology, and Materials Science	CCM	Predicts properties, and simulates the behavior, of chemicals and materials for DoD applications. Methods ranging from quantum mechanical, atomistic, and mesoscale modeling, to multiscale theories that address challenges of length- and time-scale integration, are being developed and applied. Of recent emerging interest in the CCM CTA are methodologies that cover bioinformatics tools, computational biology, and related areas, such as cellular modeling.
Computational Electromagnetics and Acoustics	CEA	Provides high-resolution multidimensional solutions of electromagnetic and acoustic wave propagation, and their interaction with surrounding media.
Climate/Weather/Ocean Modeling and Simulation	CWO	Involves accurate numerical simulation and forecast of the Earth's atmosphere and oceans on those space and time scales important for both scientific understanding and DoD operational use.
Signal/Image Processing	SIP	Extracts and analyzes key information from various sensor outputs in real-time; sensor types include sonar, radar, visible and infrared images, signal intelligence, and navigation assets.
Forces Modeling and Simulation	FMS	Focuses on the research and development of HPC-based physical, logical, and behavioral models and simulations of battlespace phenomena in the correlation of forces.
Environmental Quality Modeling and Simulation	EQM	Involves the high-resolution modeling of hydrodynamics, geophysics, and multi-constituent fate/transport through the coupled atmospheric/land surface/subsurface environment, and their interconnections with numerous biological species and anthropogenic activities.
Electronics, Networking, and Systems/C4I	ENS	Focuses on the use of computational science in support of analysis, design, modeling, and simulation of electronics from the most basic fundamental, first principles physical level to its use for communications, sensing, and information systems engineering; activity ranges from the analysis and design of nano-devices to modeling systems-of-systems.
Integrated Modeling and Test Environments	IMT	Addresses the application of integrated modeling and simulation tools and techniques with live tests and hardware-in-the-loop simulations for the testing and evaluation of DoD weapon components, subsystems, and systems in virtual and composite virtual-real environments.

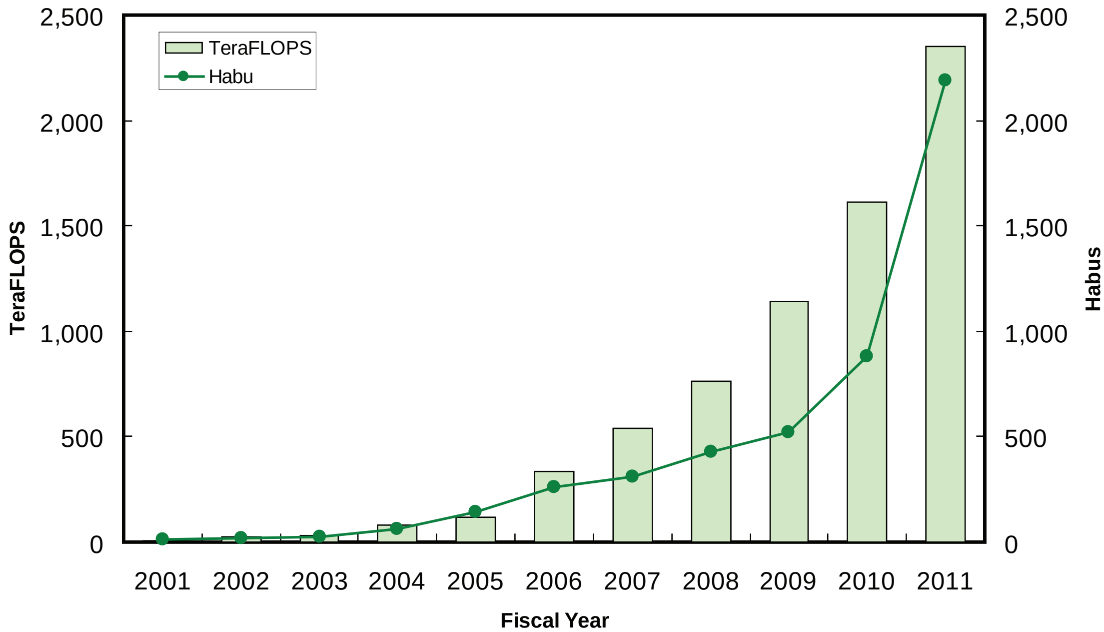


Figure 5. Total computational requirements of the HPCMP community

HPCMP Organization

The HPCMP is comprised of three major components: HPC Centers, Networking and Information Assurance, and Software Applications Support. These components provide the base of the integrated program strategy (see Figure 6) to provide a technologically advanced computational environment to support the ongoing and emerging needs of the Department's laboratories and test centers. These components are interdependent, with distinct business practices and community relationships.

The HPC Centers component includes four major shared resource centers (MSRCs) and four allocated distributed centers (ADCs). These computer centers provide DoD scientists and engineers with the resources necessary to solve the most demanding computational problems. Additional computational resources are provided

Habu—a Measure of Computational Performance

The HPCMP rates computer systems in terms of the speed at which DoD computational applications run on the systems. For the past six years, the HPCMP has run a suite of applications on existing and new systems to obtain performance comparisons. By comparing the timing results for these applications, the HPCMP is able to compare the performance of any system relative to the others. In 2002, a large IBM system located at the Naval Oceanographic Office MSRC named Habu, was designated the baseline system. Hence, performance measures are all in "Habu" equivalent units. For example, if a new system is rated at 2 Habus, that system is roughly two times more capable than a system rated at 1 Habu. That is, the new system executes the suite of applications at roughly twice the performance of the old. Of course, any individual application may run faster or slower. The line in Figure 5 shows the growth in computational requirements in Habu units of system performance.

Figure 6. HPCMP integrated program strategy

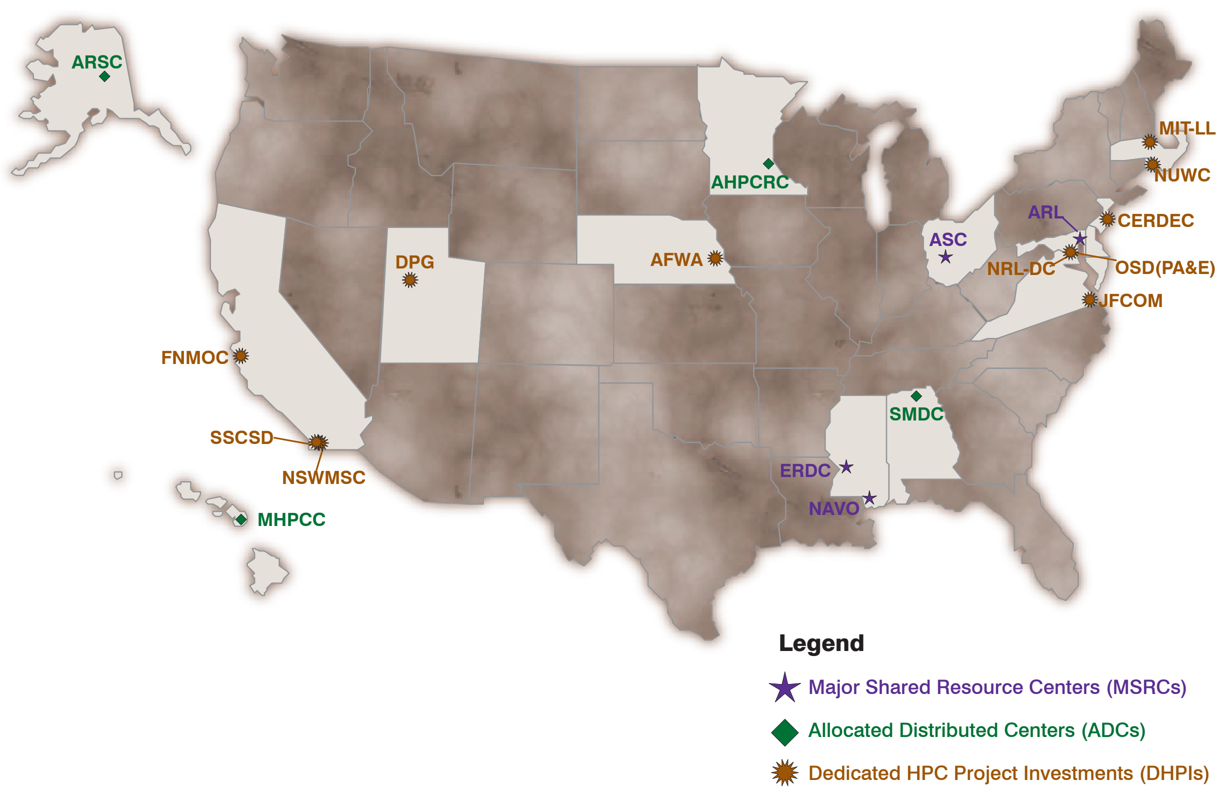


Figure 7. Location of HPCMP resources (MSRCs, ADCs, and DHPIs)

to support specific projects if those projects can not be easily addressed at the HPC Centers in a shared resource environment. These resources are termed dedicated HPC project investments (DHPIs). Figure 7 shows the MSRCs, ADCs and DHPIs.

The Networking and Information Assurance component of the HPCMP includes the Defense Research and Engineering Network (DREN). DREN provides advanced communication capabilities at faster speeds to a bigger user community than previously possible, while addressing our security requirements.

The software applications support (SAS) component provides expert services to assist our customers in most effectively using the HPC systems, provides investments in human capital across the DoD to facilitate the application of HPC tools, and supports a modest investment in a few high need HPC software applications.

DoD Challenge Projects

The HPCMP supports high priority computational work conducted within DoD that can be done at its shared resource centers through Challenge Projects. These projects represent the DoD's highest-priority, highest-impact computational work, both from technical and mission-relevance standpoints. The modeling and simulations conducted by these projects account for approximately 35% of the allocations of resources at the HPC centers. These projects range from discovering new materials using quantum chemical simulations to studying the impact of new physics in the prediction of weather. There were 37 active DoD Challenge Projects in FY 2006—23 continuing projects and 14 new projects. The 14 new projects were selected from 29 proposals submitted by the Services and Agencies in response to the HPCMP's annual call for Challenge Project proposals. Selections were made by peer review with a panel consisting of service, agency, DoD, and external reviewers. Table 2 lists the FY 2006 DoD Challenge Projects. Almost all Challenge Project Leaders presented the results of their work at the annual Users Group Conference held in Denver, CO in June 2006.

Dedicated HPC Project Investments (DHPIs)

The HPCMP also supports high priority computational work conducted within DoD that requires dedicated HPC resources. These projects typically have a need for quick turnaround of the computational work, either actual real-time or near-real-time calculations often in support of a specific test event. Such requirements are met through the HPCMP's implementation of DHPIs. These small to medium-sized projects require HPC resources that have one or more of the following attributes:

- require access to data or computational resources under time critical constraints that can not tolerate network latency or shared computing;
- signal image processing real-time attribute;
- embedded systems applications;
- dedicated computational resources available immediately as needed;
- early access technology evaluation;
- require special operational considerations, including security requirements or unconventional operations.

Examples of the types of projects supported by DHPI resources include:

- real-time analytic and decision support in test and evaluation of land combat systems;
- platform for conducting operational tests of weather research and forecast models;

Table 2. FY 2006 DoD Challenge Projects

Project Title	Project Leader/Organization
Advanced Chemical Oxygen-Iodine Laser Technology Development Using 3-D Navier-Stokes Simulation	Timothy Madden, Air Force Research Laboratory, Kirtland AFB, NM
Applications of Time-Accurate CFD in Order to Account for Blade-Row Interactions and Distortion Transfer in the Design of High Performance Military Fans and Compressors	Steven E. Gorrell, Air Force Research Laboratory, Wright-Patterson AFB, OH
Applied Computational Fluid Dynamics (ACFSD) in Support of Aircraft-Store Compatibility and Weapons Integration	Jacob Freeman, Air Force SEEK EAGLE Office, Eglin AFB, FL
Characterization and Prediction of Stratospheric Optical Turbulence for DoD Directed Energy Platforms	Frank H. Ruggiero, Air Force Research Laboratory, Hanscom AFB, MA
Computational Simulations of Combustion Chamber Dynamics and Hypergolic Gel Propellant Chemistry for Selectable Thrust Engines in Next Generation Guided Missiles	Michael Nusca and Michael McQuaid, Army Research Laboratory, Aberdeen Proving Ground, MD
Computational Studies of Naval SONAR and NVRAM Devices	Andrew M. Rappe, University of Pennsylvania, Philadelphia, PA
Computer Design and Simulation of Molecular Devices and Energy Sources for Naval Applications	Mark R. Pederson, Naval Research Laboratory, Washington, DC
Coupled Aircraft/Ship Performance Prediction for Dynamic Interface	Susan Polsky, Naval Air Warfare Center, Aircraft Division, Patuxent River, MD
Coupled CFD/CSM/DPM Modeling of Structure Response to Blast Loading	Joseph D. Baum, Science Applications International Corporation, McLean, VA (Defense Threat Reduction Agency)
Design of Energetic Ionic Liquids	Jerry Boatz, Air Force Research Laboratory, Propulsion Directorate, Edwards AFB, CA
Design of Materials for Laser Protection Applications	Ruth Pachter, Air Force Research Laboratory, Materials and Manufacturing Directorate, Wright-Patterson AFB, OH
Distributed Pump Jet Propulsion (DPJP) for Submarines	Joseph Gorski, Naval Surface Warfare Center, Carderock Division, West Bethesda, MD, and Robert Kunz, Pennsylvania State University, State College, PA (Office of Naval Research)
Dynamic Rotorcraft Simulations for Accurate Interactional Aerodynamics and Performance Prediction	Mark Potsdam, US Army Aviation and Missile Command, Moffett Field, CA
Explosive Structure Interaction Effects in Urban Terrain	James T. Baylot, Army Engineer Research and Development Center, Vicksburg, MS
First-Principle Predictions of Crystal Structure of Energetic Materials	Krzysztof Szalewicz, University of Delaware, Newark, DE (Army Research Office)
Global Ocean Prediction with HYCOM	Alan Wallcraft, Naval Research Laboratory, Stennis Space Center, MS
High Accuracy DNS and LES of High Reynolds Number, Supersonic Base Flows and Passive Control of the Near Wake	Hermann Fasel, University of Arizona, Tucson, AZ (Army Research Office)
High Fidelity Electromagnetic Target Signatures for Combat Identification	Mary Ann Gualtieri, Air Force Research Laboratory, Sensors Directorate, Wright-Patterson AFB, OH

Table 2. FY 2005 DoD Challenge Projects—continued

Project Title	Project Leader/Organization
High Resolution Simulation of Full Aircraft Control at Flight Reynolds Numbers	Scott Morton, US Air Force Academy, Colorado Springs, CO
Hypersonic Scramjet Technology Enhancements for Long Range Interceptor Missile	Kevin Kennedy, US Army Aviation and Missile Command, Redstone Arsenal, AL and CRAFT Tech, Dublin, PA
Millimeter-Wave Radar Signature Prediction Improvement for Ground Vehicles	William Coburn, Army Research Laboratory, Aberdeen Proving Ground, MD
Modeling Breaking Ship Waves for Design and Analysis of Naval Vessels	Dick K.P. Yue, Massachusetts Institute of Technology, Cambridge, MA (Office of Naval Research)
Molecular Rotors for Nanotechnology	Josef Michl, University of Colorado, Boulder, CO (Army Research Office)
Multidisciplinary Computational Terminal Ballistics for Weapons Systems	Kent Kimsey and David Kleponis, Army Research Laboratory, Aberdeen Proving Ground, MD
Multi-Scale Predictability of High-Impact Weather in the Battlespace Environment	James Doyle, Naval Research Laboratory, Marine Meteorology Division, Monterey, CA
Multiscale Simulations of Nanotubes and Quantum Structures	Jerry Bernholc, North Carolina State University, Raleigh, NC (Office of Naval Research)
Prediction Capability for High-Speed Surface Ships	Joseph Gorski, Naval Surface Warfare Center, Carderock Division, West Bethesda, MD
Scalable Multiscale Simulations of Material Behavior at the Nanoscale	Rajiv K. Kalia, Aiichiro Nakano, and Priya Vashishta, University of Southern California, Los Angeles, CA (Army Research Office)
Simulation of a Dynamically Maneuvering Unmanned Combat Air Vehicle	Raymond Gordnier, Air Force Research Laboratory, Wright-Patterson AFB, OH
Simulation of Enhanced Explosive Devices in Chambers	John B. Bell, Lawrence Berkeley National Laboratory, Berkeley, CA (Defense Threat Reduction Agency)
Simulations for Microbubble Drag Reduction at High Reynolds Number	Martin Maxey, Brown University, Providence, RI (Defense Advance Research Projects Agency)
Solidification of Complex High Temperature Structural Analysis	Christopher Woodward, Air Force Research Laboratory, Materials and Manufacturing Directorate, Wright-Patterson AFB, OH
Statistical Fatigue and Residual Strength Analysis of New and Aging Aircraft Structure	Scott Fawaz, US Air Force Academy, Colorado Springs, CO
Time-Accurate Coupled CFD/RBD Simulations of Free Flight Aerodymanics of Guided Weapons	Jubaraj Sahu, Army Research Laboratory, Aberdeen Proving Ground, MD
Tip-to-Tail Turbulent Scramjet Flowpath Simulation with MHD Energy Bypass	Datta Gaitonde, Air Force Research Laboratory, Wright-Patterson AFB, OH
Toward a High-Resolution Global Coupled Navy Prediction System	Julie McClean, Naval Postgraduate School, Monterey, CA
Virtual Prototyping of Directed Energy Weapons	Keith Cartwright, Air Force Research Laboratory, Kirtland AFB, NM

- real-time global-scale computer-generated forces experimentation;
- real-time hardware-in-the-loop avionics and weapon systems simulations for test and evaluation;
- modeling and simulation of command, control, communication, computers, intelligence, surveillance and reconnaissance (C4ISR) electronic systems under realistic tactical conditions; and
- real-time data imaging of aerial objects.

The HPC systems are procured either through the annual technology insertion process (TI-XX) that acquires new computational capability for HPCMP centers, or by providing procurement funding for the systems directly to the user site that proposed the dedicated HPC project.

Four DHPIs awards were made in FY 2006; these include projects to be hosted at: (1) Dugway Proving Grounds, UT for extending the existing four-dimensional weather system to support ensemble prediction techniques to provide probability distribution of weather variables across the test range, (2) the Army Communications Electronics Research and Development Engineering Center at Fort Monmouth, NJ for use of high-fidelity software models to perform analyses of integrated C4ISR technologies and phenomena, and (3) MIT Lincoln Laboratory, Lexington, MA to expand parameter spaces and problem sizes that can be exploited and translated into DoD systems that are better able to detect faint enemy signals, analyze intelligence and reconnaissance, and intercept ballistic missiles. A fourth project was subsequently terminated prior to resource procurement because of a loss of critical project technical expertise.

User organizations that were awarded HPC resources to support their projects in prior years and reached milestone completion presented reports at the annual Users Group Conference in June 2006. A typical DHPI has a life-cycle of two to three years, depending on the project's established milestones. In FY 2006, six DHPI projects from the following sites were transitioned from HPCMP oversight: Joint Forces Command, Fleet Numerical Meteorology and Oceanography Center/Air Force Weather Agency, Army Technical Center, Naval Surface Warfare Center, Carderock Division, Air Force Seek Eagle Office, Arnold Engineering Development Center, and Naval Research Laboratory. Accordingly, the following DHPIs are currently under HPCMP oversight:

- Naval Undersea Warfare Center, Newport, RI;
- Space and Naval Warfare Systems Center, San Diego, San Diego, CA;
- MIT-Lincoln Labs, Bedford, MA;
- Command Electronics Research, Development and Engineering Center, Ft. Monmouth, NJ; and
- Dugway Proving Grounds, Dugway, UT.

Figure 8 lists the DHPIs for FY 05, FY 06, and FY 07.

Capability Applications Projects (CAPs)

Starting in FY 2005, the HPCMP made available newly acquired systems for capability applications projects, designed to test key DoD application codes on a substantial portion of entire HPC systems and solve large problems quickly. Thus, the goals of capability applications projects are:

- to quantify the degree to which important application codes scale to thousands of processors; and
- to enable new science and technology by applying these codes in dedicated, high-end, capability environments.

Dedicated HPC Project Investments
FY 2005–FY 2007

FY07

Application of HPC to Support Operational Use of CT-Analyst
Naval Research Laboratory, Washington, DC and Navy Special Warfare Command Mission Support Center, Coronado, CA

Distributed Continuous Experimentation Environment, Interactive Joint Features Laboratory
Joint Forces Command, Suffolk, VA

Joint Ensemble Forecast System
Air Force Weather Agency, Offutt AFB, NE and Fleet Numerical Meteorology, Oceanography Center, Monterey, CA

Joint Warfare Systems Server
Office of the Secretary of Defense (Program Analysis & Evaluation), Washington, DC

FY06

Interactive Algorithm Development for WMD Defense
Massachusetts Institute of Technology-Lincoln Laboratory, Lexington, MA

Operational, Probabilistic, Numerical Weather prediction at High Resolution,
Dugway Proving Ground, UT

Virtual Electronic Battlefield
Command Electronics Research, Development and Engineering Center, Ft. Monmouth, NJ

FY05

Aircraft Store Certification
Arnold Engineering Development Center, Arnold AFB, TN and Air Force Seek Eagle Office, Eglin AFB, FL

Concurret Computation and Utilization Environment
Naval Surface Warfare Center, Bethesda, MD

Space Situational Awareness
Air Force Maui Optical & Supercomputing Site, Kihei, HI

Torpedo Hardware-in-the-Loop Modeling & Simulation,
Naval Undersea Warfare Center, Newport, RI

Figure 8. Dedicated HPC Project Investments for fiscal years 05 through 07

The process is an extension of pioneer usage of new HPC systems, but it focuses much more heavily on true capability use for a short time before those systems are put into allocated operational use. It is implemented in two phases: Phase I, which focuses on scalability testing of applications codes proposed for CAPs, and Phase II, during which a subset of successfully tested codes and projects have dedicated access to the newly acquired systems for production work to solve a large, significant problem. The period of time dedicated to this capability workload typically lasts from one to three months.

Because of late delivery of TI-06 systems, there were no CAPs executed in FY 2006. FY 2007 plans include the execution of CAPs on most of the TI-06 systems in addition to several of the TI-07 systems. A report on those projects will be made in the FY 2007 Annual Report. In the interim, a vignette of one effort nearing completion appears on page 18.

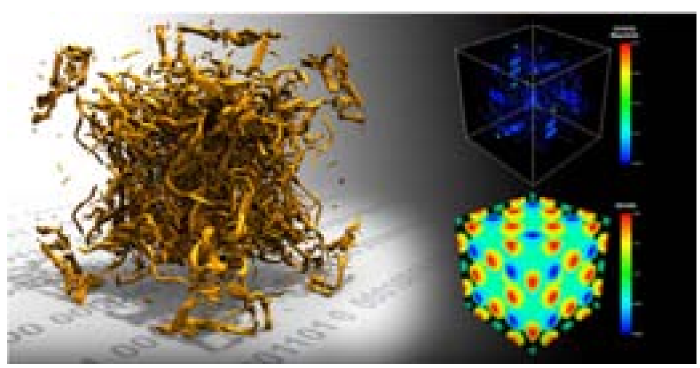
Computational Research and Engineering Acquisition Tools and Environments (CREATE)

Computer power has grown exponentially during the last 60 years. By 2012, the DoD computational science and engineering community will have access to computers with peak processing speeds in the petaFLOPS (10^{15} FLOPS) range. Computer power of this magnitude offers the potential for DoD computational applications to employ highly accurate numerical methods, include all physical effects known to be important, predict the behavior of a complete system like an entire airplane, and obtain results quickly enough that users can make parameter and sensitivity studies. Such computer power has the potential to give DoD engineers the opportunity to produce improved designs and detect and fix design flaws before major schedule and funding commitments have been made.

Realizing this potential will require development of new software applications to incorporate complete sets of accurate models and exploit the power of these new, massively parallel and very complex supercomputers. In the past, DoD relied heavily on application codes developed by other agencies such as the Department of Energy (DOE), National Aeronautics and Space Administration (NASA), academia, and commercial vendors. However, in the future DoD will need to develop more of its engineering design and analysis tools.

Parallel Algorithms for Computational Fluid Dynamics Simulations of Turbulence

Aircraft designs require an understanding of subsonic jet flows, modeling accurately and rapidly the nozel geometry, flow structures produced by the interaction, and merger of co-rotating wing-tip vortices generated in flight. Recently, collaborators at the Air Force Research Laboratory and the College of William & Mary completed the largest computational fluid dynamics simulations of turbulence to date using a unique parallel computing approach. They did so on the newest DoD supercomputer, located at the NAVO MSRC at the Stennis Space Center in Mississippi, through a Phase II CAP titled "Quantum and Entropic Algorithms for MHD and Turbulent Flows."



Entropic 27-particle lattice Boltzmann simulation of turbulence.

They tested new sub-grid models of turbulence developed by their group, using lattice Boltzmann equation techniques, an entropic method and a Smagorinsky closure method. These CAP II simulations took over 500,000 hours, used a dedicated block of thousands of high performance processors over the period of a few weeks, and generated terabytes of data per day. These large-scale simulations provide a better understanding of the morphological evolution and structural development of turbulence in fluids.

A single job took many days on 2048 processors on the system.

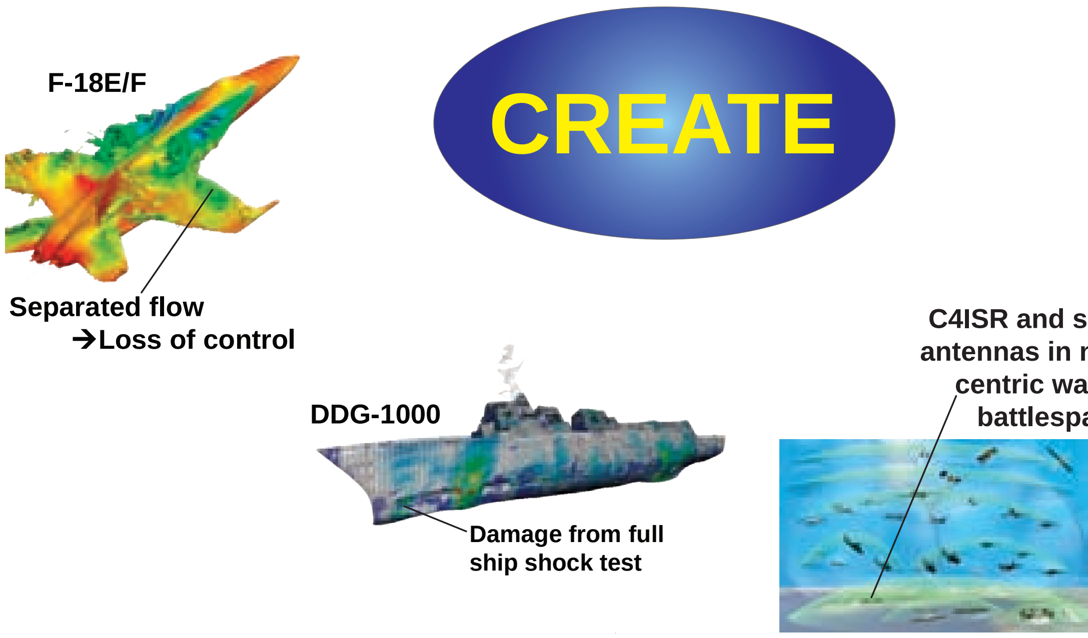


Figure 9. Examples of aircraft design, ship design, and antenna design

The reasons for this are:

1. other government agencies are focusing on their own mission requirements;
2. the market niche is too small to allow vendors to be commercially successful; and
3. developing new large-scale, massively parallel tools is an expensive, long-term effort.

The recent Quadrennial Defense Review (2006, pp. 4, 67–71), and the 2006 Government Accountability Office report (GAO-06-585T, 2006) highlight the need to improve the DoD acquisition process. Consequently, during FY 2006, the HPCMP community proposed the CREATE program as an initiative in the budget process.

Present acquisition programs largely follow a "build, test and break, fix, build, ..." methodology. This results in late discovery of design flaws, immature technologies issues, and system integration problems, causing costly rework and redesign that contribute substantially to cost overruns and schedule delays. Optimized engineering designs developed early in the acquisition process using the CREATE tools will substantially reduce costs, shorten schedules, increase design and program flexibility and agility. Above all, CREATE will improve acquisition program performance by reducing design flaws, developing sound engineering designs quickly and flexibly, and will enable the systems integration engineering process earlier in the acquisition process.

The CREATE program will develop and deploy three sets of advanced computational engineering design tools for acquisition programs:

1. military aircraft design,
2. military ship design, and
3. antenna design and integration with platforms.

These are illustrated in Figure 9.

The military aircraft design project will develop a design optimization tool to simulate unsteady, separated flow, initially for individual aircraft components and ultimately for an entire aircraft. The military ship design project will develop and

deploy accurate physics-based models for navy vessels to address ship shock response and hydrodynamics. The antenna design project will build an efficient electromagnetic design code that incorporates modern physics and computational algorithms for high performance computers. This new generation of computational design tools will enable acquisition system engineers to rapidly produce optimized designs for complete systems and make better design decisions than previously possible. A fourth project will provide software development support to these three projects for problem generation, software engineering, collaboration tools, data assessment and analysis, and computational mathematics.

The CREATE projects will be managed to provide enhanced engineering design tools within three to four years after the projects begin. Fully mature tools will be delivered at the end of 12-year project schedule including two years for planning and project design.

The CREATE community is now developing a plan for initiating the CREATE program. That plan is based on the "lessons learned" from similar scale projects carried out by nuclear weapons, climate modeling, and other computational communities, and will build on the DoD experience with the HPCMP institutes and portfolios. The CREATE 12-year budget is about $350M, with a 70% contribution from OSD and a 30% matching contribution from the services. The tri-service T&E communities will provide validation experiments and data for the projects as well.

Highlights of Impact in FY 2006

The High Performance Computing Modernization Program provides some of the tools the Department needs to address defense problems. These tools include modern high performance computing hardware, software and networking. Our scientists and engineers use these tools to solve many critical problems faced by the Military Departments and Defense Agencies.

Some problems are of immediate concern, while others are of longer-term interest. Thus, program investments impact both short-term and long-term issues. The following vignettes serve as overviews of some highlights that occurred in FY 2006.

Detection of Moving Targets in Heterogeneous Radar Clutter Scenarios

Surveillance of the ground by air- and space-borne sensors has proven to be essential to the warfighter and the intelligence community. More specifically, the DoD's 2006 Quadrennial Defense Review highlights the need for "a highly persistent capability to identify and track moving ground targets in denied areas". Ground moving-target indication (GMTI) radar has important advantages over other sensing technologies (like optical sensors) because of features such as day/night/all-weather operation and penetration of foliage, obscurants, smoke and dust.

However, radar echoes from targets have to compete with strong ground clutter returns. The target detection performance of conventional moving target indication radar is strongly degraded by the radar platform motion, due to the Doppler spread of the returns, causing difficulty in detecting slow targets. For example, for a satellite most moving targets are 'slow'. Space-time adaptive processing (STAP) is a signal and image processing technique capable of compensating for the platform motion so that optimum detection of slow moving targets is possible. Development and efficient implementation of robust STAP algorithms are particularly important as the processing involves high-dimensional vectors and matrices, rendering it computationally intensive.

The core computational problems of STAP algorithms usually do not have analytical solutions, and thus extensive Monte Carlo simulations are required. Radar systems operate typically at false alarm rates of 10^{-6}–10^{-8}, and as a result performance evaluation using Monte-Carlo methods requires 10^{8}–10^{10} independent trials for each configuration (e.g., different frequency, azimuth angle). With the computational capabilities available to researchers at the Air Force Research Laboratory Sensors Directorate's Electromagnetic Scattering Branch (AFRL/SNHE), based at Hanscom AFB, MA, these simulations took days and even months for certain cases involving data provided by the Defense Advanced Research Projects Agency's Knowledge Aided Sensor Signal Processing and Expert Reasoning program. High performance computing offers a clear opportunity for reducing simulation time.

As part of a year-long project, the PET SIP and IMT teams helped to reduce significantly these simulation times via the use parallel MATLAB® software and expertise. For example, by using just 100 processors on the JVN system at the Army Research Laboratory MSRC, the STAP algorithms ran 35 times faster. According to Dr. Freeman Lin from AFRL/SNHE:

"On my PC, the CPU time for each point took 76 seconds. This translates to the fact that if I compute 91×128 thresholds on my PC, it would take almost 246 hours. On the ARL MSRC system, where you computed 91×128 thresholds, it took 7 hours, which is 35 times faster. This is a tremendous improvement!"

GMTI Lynx radar sample image (from DARPA Affordable Moving Surface Target Engagement)

Modeling Baghdad — Including Human Factors

On a hot summer day in Iraq, US soldiers fight a low-intensity counterinsurgency battle on the streets of Baghdad. At 10 a.m., a truck parks near a warehouse in a crowded part of town. The truck explodes, killing the men inside and one of the soldiers standing guard.

After securing the area, the remaining soldiers sound the alarm and call for help. Onlookers gather — some cursing the bombers and others cursing the Americans for attracting the attack. Eventually, emergency responders arrive and begin to treat the wounded and quell the mob.

If it had occurred in the real world, this scenario generated in a DoD simulation would have immediate and future repercussions in the neighborhood, the country and the Middle East.

DoD creates hundreds of similar scenarios in the largest modeling and simulation environment that the Department has ever built. The Department uses the simulated environment for a set of experiments known as Urban Resolve 2015. Those experiments are redefining the way the military operates in urban environments. Urban Resolve is also changing the way DoD develops concepts, procures technology and conducts training.

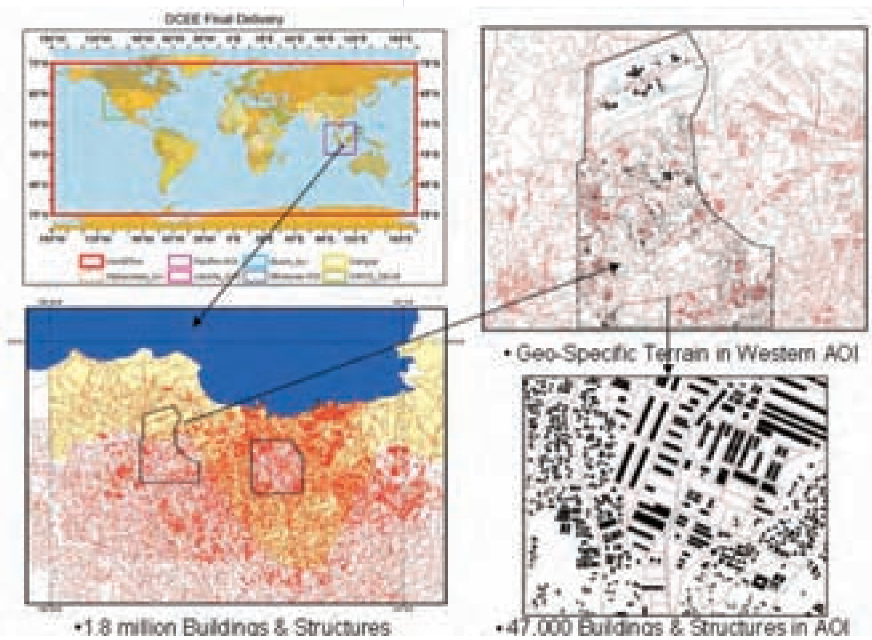
The Joint Forces Command's (JFCOM) experimentation directorate often brings new concepts into JFCOM training centers to benefit soon-to-be-deployed solders.

Urban Resolve is the most important and complex experiment conducted since Millennium Challenge 2002. That 2002 experiment took three years to plan and cost about $250 million. DoD developed Urban Resolve in half the time and spent about $22 million.

There are other differences between the two. Millennium Challenge was mostly a live simulation in which 14,000 people spent about three weeks in the field. Urban Resolve relies on virtual operations in which people control computer entities and so-called constructive operations in which computer simulations run independently.

But the biggest differences between Urban Resolve and its predecessors are its size, architecture and ambitious intent. With modeling and simulation of civilian behavior still in its infancy, the most difficult aspect of Urban Resolve is its model of human behavior, which includes political, military, economic, social, infrastructure and information factors.

In JFCOM's war game operations room, more than 100 DoD employees and contractors work at virtual posts, waiting for something to happen. Each belongs to one of three teams: the blue team of coalition forces, the red team of enemy forces, or the green team of Iraqi security forces and civilians. The operations room is their command center.



Multi-Resolution Synthetic Environment

The team members play Urban Resolve in real time at 19 networked sites nationwide. Players control the blue team forces from Fort Knox, KY and Fort Benning, GA. Others control the red forces from Fort Belvoir, VA, and the green team from the Space and Naval Warfare Systems Command in San Diego, CA.

Each site contributes simulations to Urban Resolve. Its service-oriented architecture brings together 28 separate simulations in a federated command and control environment.

Based on data provided by the National Geospatial-Intelligence Agency, two Linux-based supercomputers (one at the Aeronautical Systems Center and the other at the Maui High Performance Computing Center) simulate every building in Baghdad, including its exact size and location.

The simulation includes two million individual entities, such as people and cars. In that environment, people wake up in their homes in the morning, go to work and create morning traffic jams. Religious people pray at mosques five times a day.

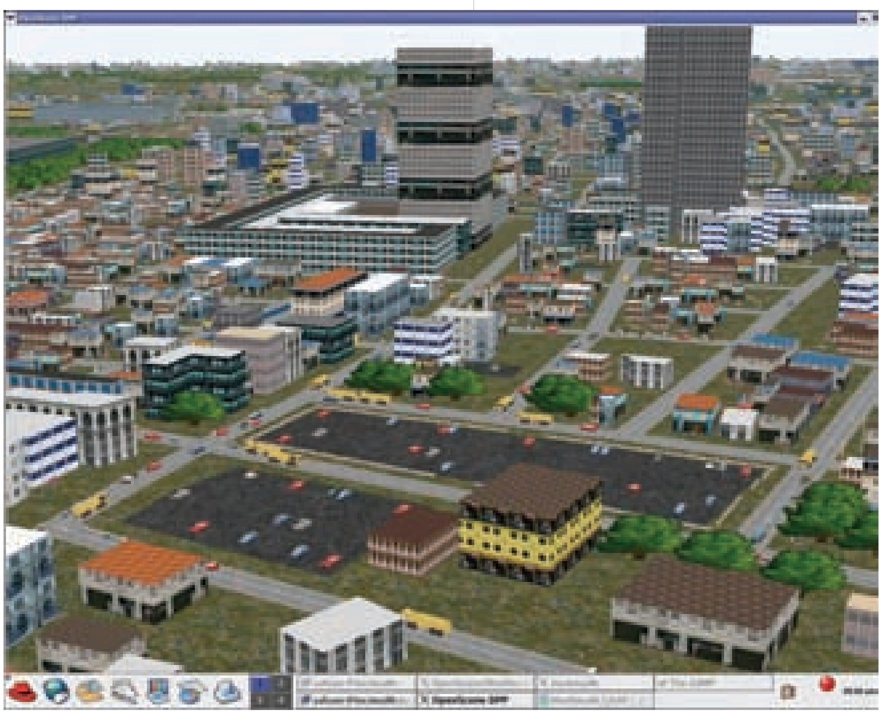
Urban Resolve has two purposes. First, it will help DoD develop new concepts for fighting in and stabilizing urban environments. In addition, it will let the Department test new capabilities for winning conflicts in those situations. JFCOM chose Baghdad for its simulation because it has a great deal of information about the city, but the experiment is relevant to all urban operations.

Urban Resolve completed three phases in 2006. In August, JFCOM pitted a 2005 US force—with current technology and policies —against insurgents in the year 2015. The experiment identified planning and readiness shortfalls and the risk of not modernizing the force. The experiment assumes that insurgents in 2015 will have more dangerous weapons, including radiological, chemical and biological agents, in addition to better technological capabilities.

In a second phase, DoD updated the US forces with capabilities included in the Army's budget plans to determine whether they are sufficient. Those capabilities include the use of radio frequency identification tagging to track the movement of warfighters and supplies.

In a third phase, the US forces used experimental concepts and technologies that are not in DoD's funding plans. Phase 3 tested future concepts, such as the Joint Command Post of the Future, which facilitates joint command and control, and the Communications Strategy Board, which integrates public affairs strategy with information operations and intelligence efforts.

Urban Resolve represents the first time DoD has used a full complement of military, political, economic, social and other human factors in modeling and simulation. Urban Resolve would not have been possible without HPC.



Urban Setting for Experiments: How to fight an asymmetric enemy in 2015

Section 2
Performance Results

Section 2
Performance Results

FY 2006 Operations and Performance

The worked accomplished in FY 2006 continues to assist the DoD S&T and T&E communities to provide support to the warfighter. Benefits are both near-term, that is, within the present fiscal year, and far-term.

This section is organized by the goals of the HPCMP.

Determining the DoD HPCMP Value to the Warfighter — Return on Investment (ROI)

The DoD HPCMP resources are a fundamental enabling technology at DoD laboratories and test centers for developing future capabilities and for responding to immediate combat threats. Over the years, there have been many examples that confirm that the HPCMP resources provide high value for the warfighter, and recently this value was quantitatively demonstrated.

In FY 2006, the HPCMP began an extensive and comprehensive exploratory process to quantify the program's value to the DoD by conducting a ROI study of a subset of high importance projects supported by the program. This pilot study examined the armor/anti-armor lethality, vulnerability, and survivability portfolio to validate the ROI process and methodology and to determine the value of this portfolio to the DoD.

The Joint Interoperability Test Command was the lead in interviewing program users, acquisition officers, and theater warfighters to collect and analyze data for this effort. The National Defense University and the Defense Acquisition University validated the ROI methodology and made recommendations to improve future ROI analyses.

For this pilot, the following projects were evaluated:

- thermorbaric Hellfire (AGM-114N) missile;
- Javelin missile;
- electromagnetic gun;
- Army Virtual Range program;
- smart munitions;
- Excalibur guided projectile;
- Modular Artillery Charge System (MACS); and
- terminal ballistics applied to the Armor Survivability Kit (ASK).

Approximately 45 people were interviewed, which included principal investigators, computational scientists and engineers, project managers, and military personnel who have used technologies in combat that were developed with HPCMP support.

The investment cost for each project using HPCMP centers was determined by using the program budget allocated for each major component of the program: HPC Centers, Defense Research and Engineering Network, and Software Applications Support divided by the number of

central processing unit (CPU) hours available for that year, and then allocated proportionally to each project's CPU usage. For projects using dedicated systems, the investment was the funding that HPCMP provided for that system.

Categories used to determine benefits attributable to the use of HPCMP resources are mission effectiveness, logistics, availability, and test/experimentation savings. Figure 10 shows the full taxonomy of benefits investigated for this analysis.

Taxonomy of Benefits
Mission effectiveness
Increase lethality
Enemy kills
Enemy equipment destruction
Infrastructure destruction
Decrease vulnerability
Friendly life savings
Friendly equipment savings
Logistics savings
Fewer spares
Fewer types of equipment
Reduction in training cost
Fuel savings
Better availability
Longer mean time between failures (MTBF)
Shorter mean time to repair (MTTR)
Test/experimentation savings

Figure 10. Taxonomy of Benefits used in HPCMP ROI calculations

Hellfire Missile

One project included in the ROI analysis that had a significant return on investment is the thermobaric Hellfire missile. The Hellfire is a legacy laser guided anti-armor missile that was modified for urban warfare in Iraq and Afghanistan. The goal of this modification was to develop a warhead with a longer impulse time than the legacy warhead so that it could achieve maximum destruction and lethality within buildings. The project went from concept to deployment in only 13 months, due to utilizing HPCMP resources, instead of the typical 30–36 months that would have been required without those resources. The system would not have been deployed in time to support Operation Iraqi Freedom had HPCMP resources not been employed to simulate the Hellfire warhead, sympathetic detonation, and target penetration. HPCMP-enabled simulations were used to down select warhead explosive fill options and decrease live tests planned from 20 to 6. The new warhead has been quite effective: one of the new warheads has the equivalent kill probability to three of the warheads previously used in this mission. More than 100 thermobaric Hellfires have been employed in Iraq.

"The system would not have been developed at all without HPC support to meet required timeline" – Jeff Sinclair – DTRA Hellfire Program; Maj. Gary Harrison – Navy Hellfire Program Manager

Depending on the scenario, the return on investment for HPCMP-enabled development of the thermobaric Hellfire is at least 437% and could reach as high as 14,386%.

Armor Survivability Kit (ASK)

A second example of the HPCMP value to the DoD is the Armor Survivability Kit (ASK). This project made use of HPCMP-enabled terminal ballistics simulation capabilities that have been developed over the past ten years. These simulations have been used to develop and evaluate the following:

- novel kinetic energy penetrator technologies;
- multi-function munition technologies;
- novel kinetic energy missile lethal mechanisms;
- survivability concepts for legacy & future combat systems; and
- improvised explosive device (IED) defeat systems.

The ASK was developed to protect the High Mobility Multipurpose Wheeled Vehicle (HMMWV) against IED threats in Iraq. The HPCMP-enabled terminal ballistics simulations allowed rapid down select from 60 designs to a "handful" of designs and halved the time required to deploy the kit to the warfighter. Development times for protection systems against evolving IED threats would have been three to four times longer without HPCMP asset availability. In addition, detailed information, e.g., first millisecond stress and deformation data that cannot be gathered with conventional instrumentation, was obtained through HPCMP-enabled simulations. As Lieutenant Colonel (LTC) Daniel S. Rusin, US Army, senior military engineer, stated, "The first millisecond of interaction between bullet and armor is only available using HPC assets and modeling and simulation."

Summary

Preliminary summary results for all the projects included in this pilot show an overall investment of $86 million with direct benefits between $487 million and $935 million, yielding a return somewhere between 463% and 982%. Alternatively, each dollar invested returns between $5 and $10.

Although these results will be refined as more data is collected, enough information has been gathered to make it clear that (1) HPCMP is more than paying its way in providing benefits to the warfighter, and (2) without HPCMP resources, some high-priority warfighter needs could not be satisfied.

Using ROI as the measurement, the value of HPCMP will be one of the principal performance metrics included in the annual report in future years.

"Without HPC, rapid solutions to the warfighter within their deployment timeline would be impossible" – LTC Daniel S. Rusin, US Army

Goal 1: Acquire, deploy, operate and maintain best-value supercomputers

The program provides high performance computing capabilities to the DoD S&T and T&E communities through three modes:

- major shared resource centers (MSRCs);
- allocated distributed centers (ADCs); and
- dedicated HPC project investments (DHPIs).

Major Shared Resource Centers (MSRCs)

The MSRCs are very large centers that provide leading-edge, high performance computational resources, data storage, data interpretation and HPC technical expertise to the defense community. The MSRCs are "purple", that is, they serve all DoD Services and Agencies without regard to their location or supporting organization. They are located at four government installations are listed below and shown in Figure 11:

- US Army Research Laboratory (ARL), Aberdeen Proving Ground, MD;
- Aeronautical Systems Center (ASC), Wright-Patterson AFB, Dayton, OH;
- US Army Corps of Engineers (USACE) Engineer Research and Development Center (ERDC), Vicksburg, MS; and
- Naval Oceanographic Office (NAVO), Stennis Space Center, MS.

At the beginning of FY 2006, the HPC systems at the four MSRCs had a total computational capability of 113.9 teraFLOPS (i.e., the capability to perform 113.9 trillion mathematical operations per second). During FY 2006, the HPCMP procured four very large systems for deployment at two of the MSRCs (ARL and NAVO). These new systems have a computational capability of 109.9 teraFLOPS. At the end of FY 2006, the total capability of the HPC systems at the four MSRCs stands at 223.9 teraFLOPS. The bars in Figure 12 show the computational growth in teraFLOPS as well as Habus at the four centers over the past six years, as of the end of the fiscal year. [See callout on page 11 for a definition of a Habu.]

Allocated Distributed Centers (ADCs)

To complement the computational capacity of the MSRCs, the HPCMP also supports four "mid-sized" centers that provide additional computational resources to DoD researchers. These centers are the ADCs. From the DoD's perspective, ADCs function like smaller scale MSRCs but, in addition to the DoD, may serve other customers as well. The four centers are listed below and shown in Figure 11:

- Arctic Region Supercomputing Center (ARSC), Fairbanks, AK;
- Maui High Performance Computing Center (MHPCC), Kihei, HI;

- Army High Performance Computing Research Center (AHPCRC), Minneapolis, MN; and
- Army Space and Missile Defense Command (SMDC), Huntsville, AL.

In FY 2006 the ARSC ADC continued to support open literature, DoD basic research. The academic community of users, whose research is supported by the Offices of Research in the Defense Services, has difficulty quickly obtaining the access clearances needed to use the systems located at the MSRCs. This operational model allows the ARSC to mix non-DoD university related work and DoD open literature work on the same systems; a win-win example of how the DoD leverages the use of ADCs.

Collectively, the ADCs have several large HPC systems, including a 952 dual-core Opteron processor SUN system at ARSC and a 5,120 dual-core Xeon processor Dell system at MHPCC, both added in FY 2006. The ADCs provide a total of 91.6 teraFLOPS (121.0 Habus) of computational capability to the HPCMP. Adding this computational power to the capability located at the MSRCs, the HPCMP total capability increases from 223.9 teraFLOPS (291.3 Habus) to 315.5 teraFLOPS (412.3 Habus).

Summary

The hardware and software acquisition budget for the MSRCs over the last seven years has had, for all practical purposes, zero growth. However, in FY 2001, the Program implemented an acquisition process whereby all HPCMP hardware and software is acquired through consolidated large contracts with competitively selected HPC offerings. The leveraging of volume purchasing power combined with technology advances commensurate with Moore's law (a prediction made by the former Chief Executive Officer of Intel Corporation that the number of transistors contained on a silicon chip will double every 18 months) has provided the HPCMP with computational capabilities that exceed traditional growth curves.

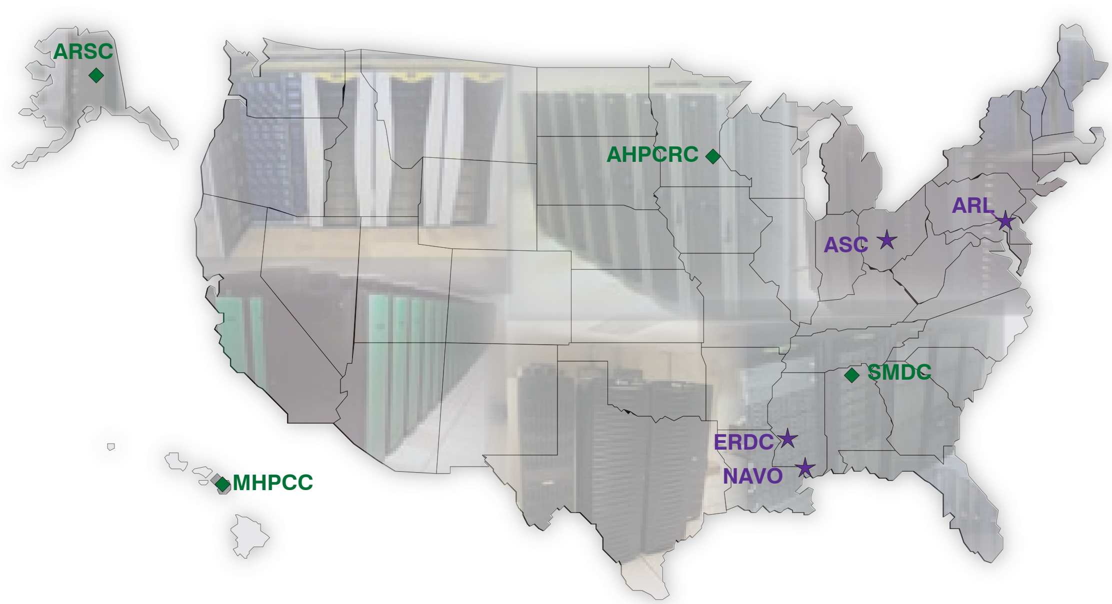


Figure 11. Location of major shared resource centers (purple) and allocated distributed centers (green)

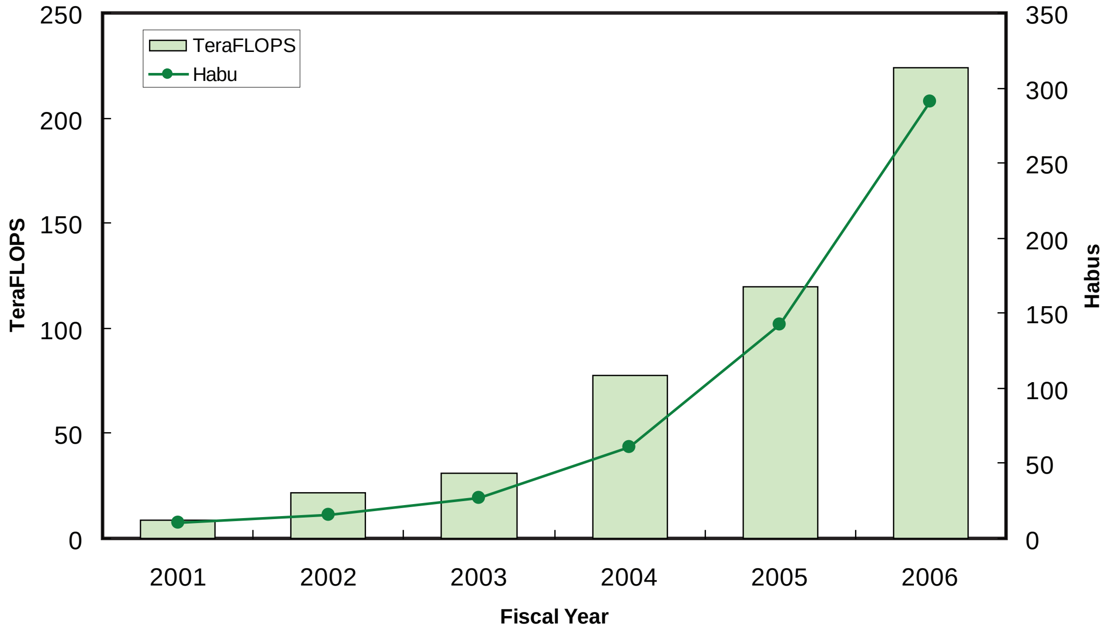
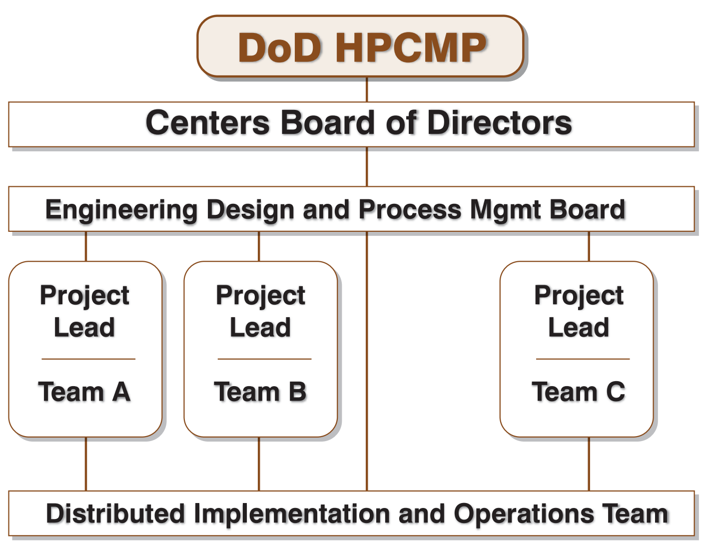


Figure 12. Growth in capability of the MSRCs as of the end of the fiscal year

Overarching Governing Infrastructure for Centers

The HPCMP community is a geographically distributed one with a valuable diversity of local skills and capabilities that must be captured in support of community ends. To achieve this transfer of best practices and innovations, an overarching centers' governing infrastructure was created:

- the center directors of the four MSRCs, plus ARSC, and MHPCC are members of the Centers Board of Directors (CBoD) for the HPCMP centers capability;
- the technical specialists that design, build, and implement the solutions comprise the Engineering Design And Process Management Board (ED&PMB); and
- the Distributed Implementation And Operations Team (DIOT), a group of individuals at each of the centers are positioned to sustain the capability.



This governing infrastructure was developed in early FY 2004 and chartered in March of 2004. The adjoining figure shows the organization of the infrastructure. The CBoD has met several times to initiate new investigations and to monitor ongoing cross-center intiatives. The other two teams address the initiatives. Unified direction from the CBoD has helped to keep the ED&PMB and the DIOT on focus.

Goal 2: Acquire, develop, deploy and support software applications and computational work environments that enable critical DoD research, development and test challenges to be analyzed and solved

The Software Applications Support (SAS) component supports Goal 2 above. SAS presently consists of three major efforts: HPC Portfolios, HPC Software Applications Institutes, and PET, formerly known as Programming Environment and Training. In FY 2007, we are planning a fourth effort, called CREATE, to build engineering design analysis tools for aircraft, ships and antennas. Execution of CREATE will start in FY 2008. The ultimate aim of SAS is to provide DoD scientists and engineers with the capability for modeling and simulating the physical world to facilitate the design, development, test, and deployment of superior weapons systems, thereby allowing our soldiers, sailors, marines, and airmen to be prepared better through training, tactics, and support systems.

HPC Portfolios

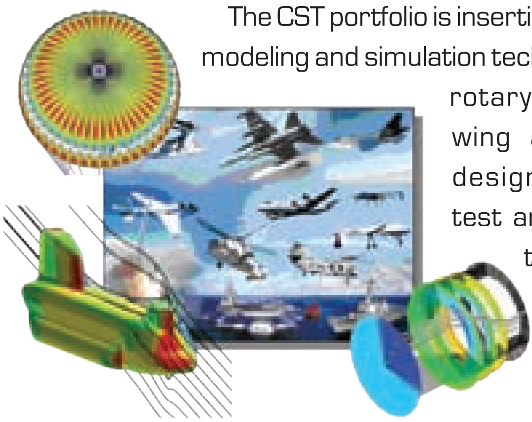
The trend in research, development, test, and evaluation clearly indicates that multidisciplinary problems will further challenge DoD scientists and engineers and require upscale HPC resources. This implies that many of tomorrow's applications will incorporate multiple computational disciplines, defined in this program by the CTAs. The portfolio effort within the HPCMP has embraced these needs. Portfolios provide efficient, scalable, portable software codes, algorithms, tools, and models and simulations that run on a variety of HPC platforms and are needed by a large number of S&T and T&E scientists and engineers to execute their missions. Portfolio development teams span DoD Services and Agencies and include algorithm developers, applications specialists, computational scientists, computer scientists and engineers, and end users.

Developing software for scalable HPC systems remains technically challenging and labor intensive. The HPCMP helps the DoD take advantage of existing and future computing and communications capabilities by building software with an emphasis on reusability, scalability, portability, and maintainability. In addition, this initiative is producing a new generation of world-class scientists and engineers trained in scalable software techniques to reduce the future costs of doing business and increase our defense capabilities. HPC portfolios focus on specific themes that encompass multiple CTAs and cross Service and Agency boundaries.

The portfolios, illustrated in Figure 13 and described in the following paragraphs, address critical needs in S&T and T&E. The resultant software codes completed in these efforts provide DoD scientists and engineers with applications software that efficiently and effectively exploits the latest generation of scalable high performance

computing systems. These applications affect the design, acquisition, and utilization of military technologies that will aid in the development of improved military capability for the 21st century.

Collaborative Simulation and Testing (CST)



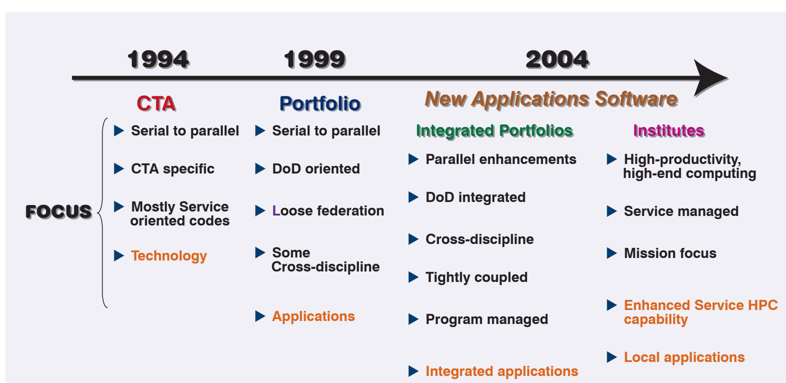
The CST portfolio is inserting high fidelity modeling and simulation technologies into rotary wing, fixed wing and airdrop design, analysis, test and evaluation throughout the product's life-cycle. The portfolio provides the warfighter with fast, state-of-the-art analysis by introducing web-based plug-and-play integration of multi-disciplinary codes on HPC systems.

The portfolio's rotary wing focus area is optimizing the design of the CH-47 and other helicopters through higher fidelity predictions of airloads and performance. Aerodynamic and structural codes have been integrated on HPC platforms, providing a state-of-the-art aeroelastic analysis capability, leading to aircraft weight reductions.

The fixed wing focus area is increasing the compatibility of engines with airframes, including Joint Strike Fighter, through simulations on HPC

Evolution of Software Applications Support within the HPCMP

An evolutionary timeline is shown below that graphically depicts how the DoD software applications programs are transitioning from CTA focused activities to ones that will lead to tightly integrated, multidisciplinary codes that tackle some of the most comprehensive and complex problems facing the DoD warfighters today. Both paradigms have evolved from individual software projects for applications codes from the mid-nineties, where the efforts focused on enhancing DoD applications codes originating up to several decades earlier. These codes were enhanced to become more robust and execute efficiently on scalable hardware coming on line in the mid-to-late nineties.

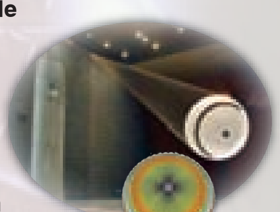


From the beginning of the software applications efforts in 1998 until today, the DoD has completed over 100 projects involving many hundreds of codes; this was a great boon to the weapons development, testing, and warfighting communities. These efforts improved the speed, complexity, and accuracy of military simulations in materials for combat platforms, space and earth weather prediction, littoral environments, weapons systems, and simulations for the battlefield. Codes released within the last few years: predict the weather with forecasting and nowcasting; model radar-based sensing of surface and subsurface targets, including land mines, unexploded ordnance, and vehicles; model 3-D rectangular arrangements such as the pulsed plasma micro-thruster for microsatellite propulsion; model and simulate large-scale military communications and tactical signal intelligence platforms, weather forecasting model improvements; and simulate large scale, heterogeneous, communication networks.

HPC Software Portfolios

Making a Difference for DoD Acquisition

Collaborative Simulation and Testing (CST)



This portfolio provides scalable software for military applications focused on collaborative simulation and testing to reduce risk in weapon system development and to provide information to senior decision makers throughout the life cycle of the systems. The products of the CST portfolio will allow for simulations and resultant data prior to a test, capture test results, perform real-time data validation of test results, and provide for data interrogation and comparisons after the test.

Multi-Phase Flow Target Interaction (MFT)

This portfolio delivers integrated, state-of-the-art, physics-based codes for the design and performance prediction of munitions. The approach is a spiral development, incorporating and integrating current understanding of phenomenology into existing, validated DoD and DOE component codes resulting in an integrated toolkit. The industrial base will use this toolkit to efficiently conceive, design and qualify new systems, considering the full spectrum of energetics technologies and applications to the United States.

Physics-based Environment for Urban Operations (PEUO)

This portfolio focuses on integrating an entity-level, urban combat model with a command and control model and a chem-bio dispersion model. The integrated portfolio is used to provide realistic training scenarios for urban combat operations. The command and control features provide physics-based radio propagation models with non-stationary networks while the chem-bio dispersion models provide real-time, weather-dependent, concentration bands of toxic cloud movement. This portfolio will provide enhanced combat training as well as domestic disaster event, recovery and relief training.

Virtual Electromagnetic Design (VED)

This highly integrated portfolio provides the DoD the ability to design, from first-principle electromagnetics, in situ wide-band, multi-functional antennas and rough surface scattering solutions for a wide range of DoD activities including communication, acquisition, target identification, surveillance, and electronic attack.

Insensitive Munitions (IM)

Munitions must reliably fulfill their performance, readiness and operational requirements on demand and minimize the probability of inadvertent initiation and severity of subsequent collateral damage to weapon platforms, logistic systems and personnel when subjected to unplanned stimuli.

DEPARTMENT OF DEFENSE · UNITED STATES OF AMERICA

HPC Modernization Program

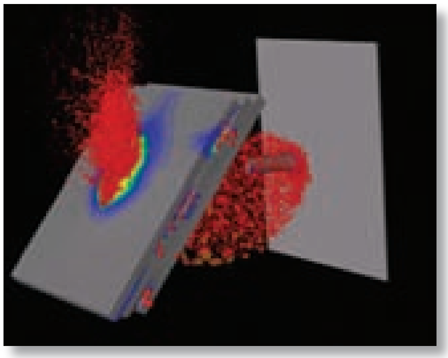
Figure 13. HPC Portfolios

platforms. High fidelity modeling of the external aircraft flow is integrated with flow predictions inside the engine to provide enhanced performance through an improved design and analysis tool for modern fan systems.

Finally, the airdrop focus area is transforming the design of parachute systems by providing HPC-based analysis capability. Computational fluid dynamics and computational structural dynamics codes have been integrated to enable a low-cost redesign of an existing parachute to increase payload weight with a minimal increase in parachute system weight.

Multiphase Flow Target Response (MFT)

The MFT portfolio is integrating state-of-the-art, physics-based codes from DoD and the DOE to provide the DoD acquisition community a common and supported toolset that delivers predictions for multiphase blast and enhanced blast weapons effects in complex military operations on urbanized terrain environments. During FY 2006, the portfolio integrated multiphase flow physics into the DOE codes, CTH, and ALE3D. A framework for turbulent mixing, gas phase chemistry and metal combustion modeling has been developed and implemented into CTH and ALE3D. The portfolio is also developing tools for insensitive munitions characterization by integrating particle methods and material models into PRESTO, a DOE code designed for problems with large deformations, nonlinear material behavior and contact.



Virtual Electromagnetic Design (VED)

This highly integrated portfolio gives DoD the ability to design from first-principle electromagnetics in-situ wideband, multi-functional antennas and rough surface scattering solutions for a wide range of DoD functions including communication, acquisition, target identification, surveillance, and electronic attack. The VED portfolio and other new improved concurrent electromagnetic particle in cell code developments permit end-to-end integrated system modeling, from pulsed power to antenna and platform. This enables time critical counter-improvised explosive device simulation, avoiding $12M and 18 months experimental cost. It further impacts airborne counter electronics efforts, avoiding expensive flight tests and reducing electromagnetic compatibility/electromagnetic interference-related problems.

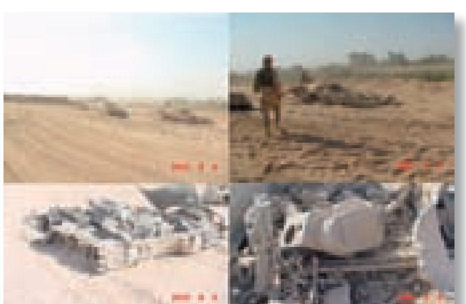
Physics-based Environment for Urban Operations (PEUO)

The PEUO portfolio focuses on integrating an entity-level urban combat model with a command and control module and a chem-bio dispersion model. The integrated software will be used by the warfighter training community to provide realistic scenarios for urban combat operations. The command and control features furnish physics-based radio propagation models with non-stationary networks while the chem-bio dispersion models provide real-time, weather-dependent, concentration bands of toxic cloud movement. The portfolio has integrated CT-Analyst software

with the One Semi-Automated Forces (OneSAF) Objective System (OOS). CT-Analyst is an efficient graphical user interface for instantaneous (50ms or less) plume rendition and situational analysis. OOS is a next-generation computer generated forces simulation. A demonstration of the integrated software has been provided for stakeholders from the US Army program Executive Office for Simulation, Training and Instrumentation who were quite impressed with the demonstration and scenario, which is running with a company moving through Baghdad and halting when they encounter a smoke cloud.

Insensitive Munitions (IM)

The HPCMP and executive agents for IM within the Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics sponsored a workshop to explore the development and fielding of computational modeling and simulation tools for IM. The first day of the workshop focused on delineating and examining the state of existing and future IM tools for the purpose of enhancing and integrating those tools to predict and minimize the response of munitions containing



explosives and propellants subject to unplanned stimuli in tactical and logistical applications. On the second day of the workshop, IM technology area leaders within DoD formed a breakout session to formulate a strategic direction for an integrated HPC-based modeling and simulation design and analysis strategy for IM. A HPC software development portfolio that will produce an integrated set of modeling software will be selected during the second quarter FY 2007.

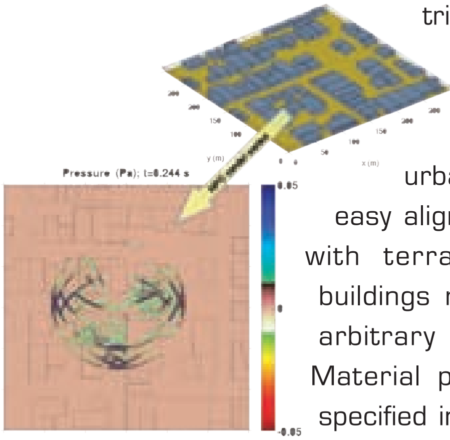
HPC Software Applications Institutes

Institutes address Service/Agency high priority, high value technology or materiel RDT&E mission priorities and augment traditional processes with computational insight by using legacy or newly-developed computational techniques. Additional information about the six institutes is contained in Figure 14 and in the following paragraphs.

Institute for Maneuverability and Terrain Physics Simulation (IMTPS)

The mission of the IMTPS is to foster a culture within DoD of using high-fidelity simulation to attack problems hindering maneuverability. The IMTPS focuses on simulating near-surface environmental processes to support: 1) detection of landmines, improvised explosive devices, and unexploded ordnance; 2) use of seismic and acoustic unattended ground sensor networks; 3) analysis of maneuverability and trafficability; and 4) remote sensing of denied areas. The IMTPS vision integrates physics-based geotechnical, geophysical, hydrogeologic, and hydrologic analyses into a virtual-testing facility for resolving terrain-related warfighter problems.

During FY 2006, the IMTPS developed conceptual modeling of an urban environment that allows the definition of buildings, terrain, sub-surface soil layers, and air layers, which can be processed to provide information for a finite difference acoustic analysis. Buildings may be defined from two-dimensional (2-D) extrusions of floor footprints defined by a geographic information system or by computer aided drafting and design data. The soil and air layering may be defined using



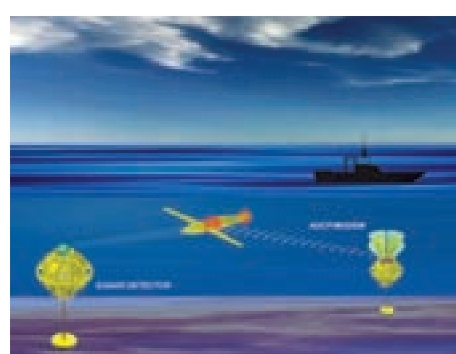
triangulated irregular networks or digital elevation models. The urban modeler allows easy alignment of buildings with terrain features and buildings may be placed on arbitrary terrain surfaces. Material properties can be specified interactively from a user defined material property table. Underground facilities and tunnels can also be modeled as extrusion of 2-D footprints. The modeler is capable of processing a virtually unlimited number of buildings and soil layers to provide finite difference meshes consisting of hundreds of millions of nodes. A major enhancement to current capabilities is the ability to model complicated building shapes that can be non-orthogonal with concavities, thus allowing real world cities to be analyzed. The urban modeler provides enhanced modeling capabilities compared to current methods of model generation and reduces the time required for model generation. This model will be used to support Army evaluation of acoustic sensors operating in an urban environment.

Biotechnology High-Performance Computing Software Applications Institute for Force Health Protection (BHSAI)

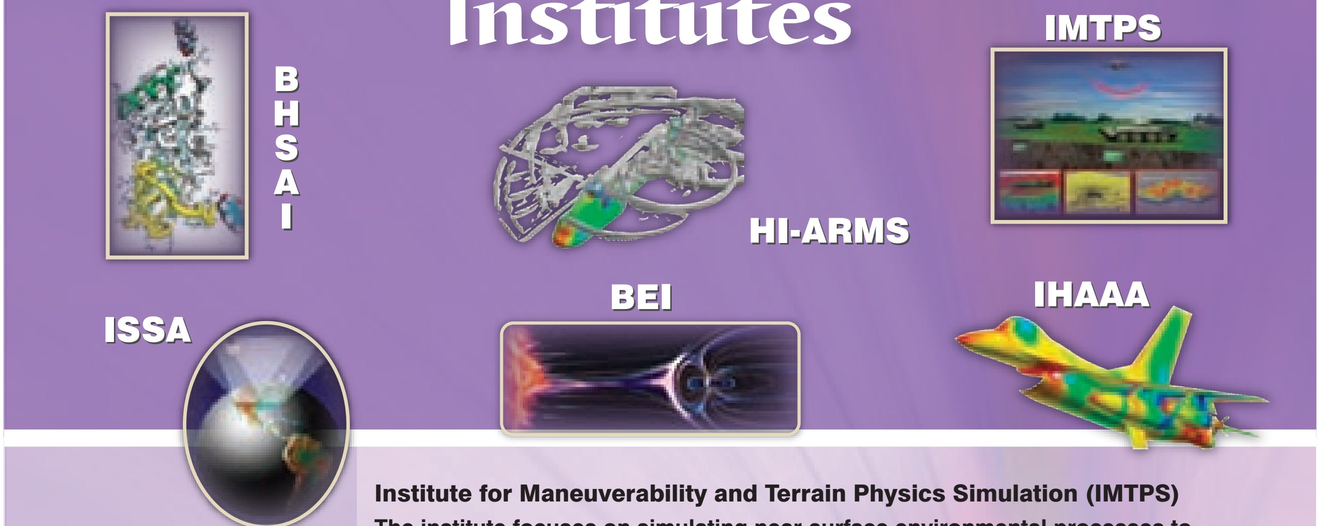
The BHSAI serves as an interdisciplinary, tri-Service resource to develop and apply HPC software that will accelerate research and development of militarily necessary medical products for DoD's Force Health Protection strategy. In force protection, the ability to rapidly differentiate between benign and pathogenic organisms is vital for battlefield treatment. The differences between a benign and pathogenic organism are impossible to distinguish by eye, necessitating chemical and biological diagnostic assays. The problem to be solved is how to distinguish between closely related species where one, *Yersinia pestis* causes plague, but another *Yersinia pseudotuberculosis* is less harmful and does not require the same intense medical intervention. During FY 2006, the institute completed development of tools to examine sequence fragments and identify short, specific and unique sequences to an organism, termed "fingerprints". The novel strategy employed by the BHSAI is to exploit small differences that do not exist in similar organisms. The US Army Medical Research Institute of Infectious Diseases has used the BHSAI's diagnostic assays to create printed custom arrays incorporating in-silico-determined fingerprints able to differentiate *Y. pestis* from *Y. pseudotuberculosis*.

Battlespace Environments Institute (BEI)

The BEI migrates existing DoD existing climate/weather/ocean modeling and simulation, environmental quality modeling and simulation, and space weather applications to the Earth System Modeling Framework (ESMF) and assists in transitioning non-DoD ESMF applications to DoD. During FY 2006, BEI used the ESMF to couple the Navy Coastal Ocean Model and Coupled Ocean/Atmosphere Mesoscale Prediction System as a single executable application. The flexible software



HPC Software Applications Institutes



Each institute has a critical mass of experts keenly focused on using computational science and high performance computing to accelerate solving the Department's highest priority challenges. With cross-Service and Agency teaming and multi-disciplinary approaches, the institutes transform traditional operational processes with computational insight by using legacy or newly-developed computational tools.

Institute for Maneuverability and Terrain Physics Simulation (IMTPS)

The institute focuses on simulating near-surface environmental processes to support: detection of landmines, improvised explosive devices, and unexploded ordnance; the use of unattended ground sensor networks; analysis of maneuver and traffic-ability; and remote sensing of denied areas.

Biotechnology HPC Software Applications Institute for Force Health Protection (BHSAI)

The institute builds HPC experience and expertise within the DoD to deliver the best medical and non-medical biotechnology solutions to protect and treat our warfighters.

Battlespace Environments Institute (BEI)

This institute migrates existing DoD climate/weather/ocean modeling and simulation, environmental quality modeling and simulation, and space weather applications to the Earth System Modeling Framework (ESMF) and assists in transitioning non-DoD ESMF applications to DoD.

HPC Software Applications Institute for Space Situational Awareness (ISSA)

The institute addresses four top priority capability shortfalls in the Space Situational Awareness community: astrodynamics, image enhancement, non-imaging space object identification, and knowledge fusion. The institute applies the power of HPC and advanced algorithms to identify the functionality, capability, mission, status, and health of space objects.

Institute for HPC Applications to Air Armament (IHAAA)

This institute identifies and integrates new technologies and rebuilds and restructures existing Service-generated software using formal software engineering procedures that will build acquisition community confidence. Greater accuracy and rapid production of HPC solutions will enable early detection of problem areas in new systems and provide quicker reaction to warfighter needs.

HPC Institute for Advanced Rotorcraft Modeling and Simulation (HI-ARMS)

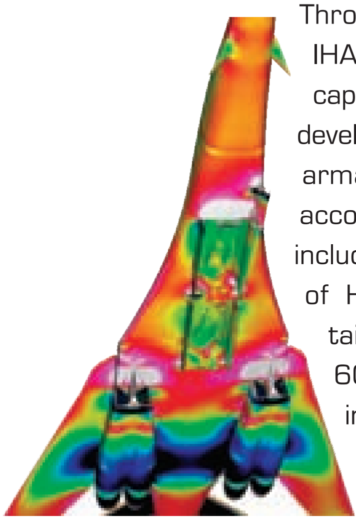
This institute significantly increases domestic capability to analyze and design future rotorcraft systems to meet heavy-lift requirements of the Department of Defense. Institute software products are built according to the physical accuracy, solution throughput and cost, and solution quality priorities necessary to create a rotorcraft design process around HPC.

Figure 14. HPC Software Applications Institutes

design provides a basis for advanced development of two-way coupling, which will be completed by the end of FY 2007. The two-way coupled ocean-atmosphere prediction system will provide realistic feedback at the air-sea interface; leading to more accurate predictions for the warfighter in littoral and deep-water areas. It may also be used for improved hurricane prediction, ocean prediction, optimum track ship routing, search and rescue, anti-submarine warfare and tactical planning.

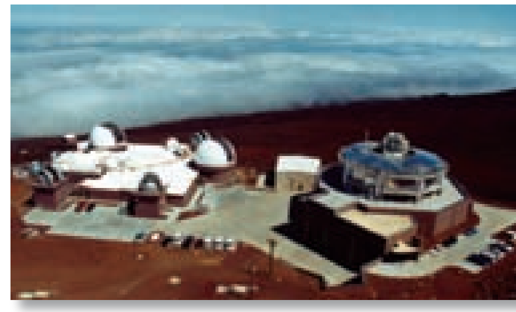
Institute for HPC Applications to Air Armament (IHAAA)

The IHAAA integrates HPC with the need to field new weapons and new weapon configurations in a rapidly changing warfare environment. Through its various projects, the IHAAA delivers faster analysis capability that translates to faster development and certification of air armament systems. Some of the accomplishments during FY 2006 include: the successful application of HPC tools to help solve a tailboom modification of the UH-60 to correct a hover problem in high cross wind conditions that avoided $200,000 in flight test costs; the timely support of a B-52 safety investigation board using HPC tools, collaboration between Naval Air Systems Command, Northrop-Grumman, and the Air Force Seek Eagle Office that resulted a $1.17M cost avoidance for pod integration on F-18; expansion of HPC application to aircraft-store compatibility analysis in stability and control and flutter; and application of HPC capability to integrate the new Miniature Air Launched Decoy on the B-52. Many of these accomplishments reduce delivery time for new war fighting capability, reduce costs to deliver this capability, or reduce limitations to system employment.



Institute for Space Situational Awareness (ISSA)

The ISSA supports the space situational awareness needs of warfighters by developing HPC software applications. SSA includes the space support and mission support foundation tiers of the United States military space power, and directly supports the missions of offensive and defensive counter-space. The ISSA is increasing combat capability by providing sharper, high resolution optical imagery of space objects of interest for space control and SSA. During FY 2006, the ISSA developed SIMFENCE, a modeling and simulation tool that simulates Space Surveillance Network (SSN) sensors and aids space surveillance systems development, architecture, and operational decision-making processes. The ISSA has also provided enhanced capability to analyze and architect SSN force structure, considering optical, infrared, and radar sensors; satellite catalog accuracy; loss satellite rates; and event detection timeliness by using HPC to improve simulation times on the SSN Analysis Model. The improvements will provide rapid SSN analysis to the warfighter. In the area of image enhancement, the ISSA has developed Physically-Constrained Iterative Deconvolution (PCID) software, which provides images that approach the theoretical limit of image quality. Dramatic decreases in execution times have been realized through software engineering and employment of HPC, thus making PCID viable for users.



HPC Institute for Advanced Rotorcraft Modeling and Simulation (HI-ARMS)

The mission of HI-ARMS is to transform the analysis-test paradigm that currently exists within the rotorcraft industry and government laboratories in the United States into one built around HPC, which will provide domestic manufacturers the means to create effective designs (or upgrades) of rotorcraft systems required by DoD and to minimize development cost and risk. Simultaneously, the DoD will have the means to accurately predict mission capability, to improve the effectiveness of vehicle test programs, and to effectively conduct rotorcraft source selection processes, including analyses required to support airworthiness qualification. Currently, HI-ARMS's work is supporting investigation of helicopter brownout which occurs when operating in unimproved landing areas, such as Middle East war zones. Improved prediction and understanding of brownout flow fields can reduce the possibility of aircraft incidents and lead to mitigation through aerodynamic design.

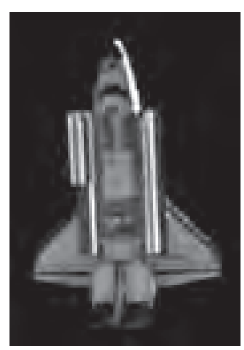
Physically Constrained Iterative Deconvolution (PCID) Algorithm

Researchers, sponsored by the Air Force Office of Scientific Research, invented the Physically Constrained Iterative Deconvolution (PCID) algorithm and proved that this algorithm achieves the theoretical limits to image quality as calculated using the Cramér-Rao lower bound of Fisher information theory.

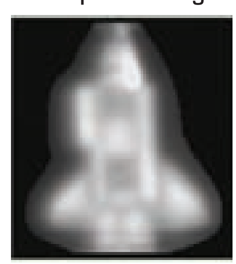
PCID is an iterative image resortation algorithm. It estimates and removes atmospheric and system blurring from one or more frames of blurred and noisy measured data to produce a single high-resolution image. It achieves, or when less computational effort is desired, closely approaches the theoretical limits to image quality. That is, PCID extracts the most amount of information that can be extracted from image data, and in this sense no better algorithm can ever be invented!

The research surrounding PCID ended the "super-resolution" controversy which had been raging for nearly a half century. It remains an open basic research question whether it is possible to create an algorithm, meeting the Cramér-Rao lower bound, which has fewer mathematical operations, and thus might be more computationally efficient.

Armed with this essential fundamental knowledge, the DoD determined sufficient computational power existed to warrant investment in a large software development effort to produce an engineering tool which would be fast enough to provide timely operational SSA to the warfighting commands. Thus, the ISSA was founded and funded.



No processing



The figure on the right is an example of the defraction limited image. The figure on the left shows the results of processing with PCID. This data consists of 300 images taken with a 1.6m telescope, and using four hours computation time on a 64 processor HPC system.

User Productivity Enhancement and Technology Transfer (PET)

PET enables the DoD HPC user community to make the best use of the computing capacity the program provides and to extend the range of DoD technical problems solved on HPC systems. PET is enhancing the total capability and productivity of the program's user community through HPC-related science and technology support, training, collaboration, tool development, support for software development, technology tracking, technology transfer, and outreach to users.

PET is responsible for gathering and deploying the best ideas, algorithms, and software tools emerging from the national HPC infrastructure into the DoD user community. The PET activities are conducted through two separate contracts; one to MOS University Consortium, led by Mississippi State University, and the second to High Performance Technologies, Incorporated. The teams from both contracts involve academic leaders to serve as points of contact for each of the areas covered by PET and experienced Ph.D.-level personnel located at DoD sites to provide HPC and one-to-one scientific assistance to HPCMP users. The teams are comprised of experts from a broad range of universities and companies highly regarded in the HPC field (see Figure 15). In addition, PET personnel lead short-term projects that focus on delivering capabilities for specific needs.

PET supports all ten HPCMP computational technology areas, and the following four crosscutting areas, with a broad HPCMP-wide management approach.

Enabling Technologies (ET)

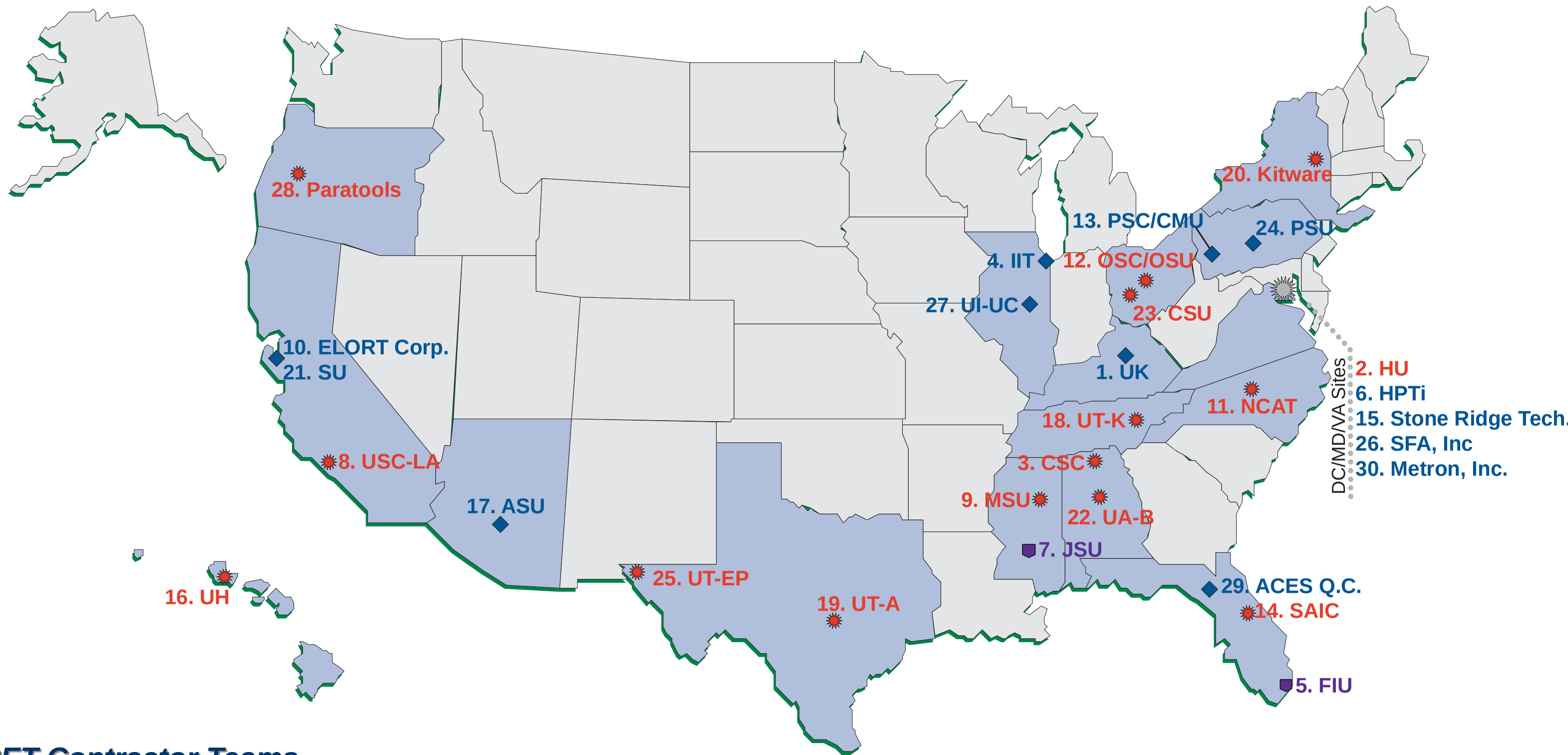
The ET functional area provides tools, algorithms, and standards for pre- and post-processing large datasets. Such processing includes the following technologies: mesh generation, visualization (both local and remote), data mining and knowledge discovery, image analysis, and problem solving environments.

Computational Environment (CE)

Improving the usability of the computational environments at the HPCMP centers is critical for easily and effectively using the program's resources. CE includes all aspects of the user's interface to high performance computing resources, such as programming environments (debuggers, libraries, solvers, higher order languages; performance analysis, prediction, and optimization tools), computing platforms (common queuing, clusters, distributed data, and metacomputing), parallel algorithms, user access tools (portals and web-based access to high performance computing resources), and consistency across the centers for locating these capabilities.

Collaborative and Distance Learning Technologies (CDLT)

This functional area focuses on supporting HPCMP users who are unable to attend HPC-based events, such as training classes and meetings. CDLT is responsible for webcasting and video-capturing events and post-processing the material to create high quality instructional content. After approval, such content is available for downloading from the PET Online Knowledge Center. CDLT also provides support for video teleconferencing services. Strong interactions with the DREN component and with Centers' staffs ensure that CDLT activities are coordinated and incorporated into the program's networking and security infrastructure.



PET Contractor Teams

1. University of Kentucky, Lexington, KY
2. Howard University*, Washington, DC
3. Computer Sciences Corporation, Huntsville, AL
4. Illinois Institute of Technology, Chicago, IL
5. Florida International University*, Miami, FL
6. High Performance Technologies, Inc., Reston, VA
7. Jackson State University*, Jackson, MS
8. University of Southern California, Los Angeles, CA
9. Mississippi State University, Starkville, MS
10. ELORT Corp., Sunnyvale, CA
11. North Carolina A&T University*, Greensboro, NC
12. Ohio Supercomputer Center/The Ohio State University, Columbus, OH
13. Pittsburgh Supercomputing Center/Carnegie-Mellon University, Pittsburgh, PA
14. Science Applications International Corporation, Orlando, FL
15. Stone Ridge Technology, Bel Air, MD
16. University of Hawaii*, Honolulu, HI
17. Arizona State University, Tempe, AZ
18. University of Tennessee, Knoxville, TN
19. University of Texas, Austin, TX
20. Kitware, Clifton Park, NY
21. Stanford University, Palo Alto, CA
22. University of Alabama, Birmingham, AL
23. Central State University*, Wilberforce OH
24. Pensylvania State University, University Park, PA
25. University of Texas*, El Paso, TX
26. SFA, Inc., Crofton, MD
27. University of Illinois, Urbana-Champaign, IL
28. Paratools, Eugene, OR
29. ACES Q.C., Gainesville, FL
30. Metron, Inc., Reston, VA

** denotes Minority Serving Institution (MSI)*

As of: October 2006

Legend

- HPTi Team
- MOS University Consortium
- HPTi and MOS

Figure 15. HPCMP PET Contractor Teams

Education, Outreach, and Training Coordination (EOTC)

This functional area coordinates formal and informal knowledge delivery to the DoD HPCMP user community and outreach to other communities. EOTC encompasses PET-sponsored HPC-based training, summer intern programs, summer institutes at minority serving institutions (MSI), visiting faculty programs, and general HPC outreach. EOTC provides opportunities for MSI staff, faculty and students; undergraduate and graduate students; postdoctoral and visiting faculty appointments; and the training of future DoD HPCMP users. Work in this functional area includes: coordinating on-site training at the program's shared resource centers and remote sites; selecting optimal training delivery methods and media; coordinating outreach forums, such as conferences, workshops, seminars, and symposia; establishing and maintaining a coherent framework to integrate undergraduate, graduate students, postdoctoral and visiting faculty into the PET activity; and developing programs and activities that promote careers in computational science and high performance computing.

PET Highlights

HPCMP technical and program management has emphasized and encouraged our entire team of functional experts, on-site personnel, principal investigators, and business administrators to focus on the key goals of PET program: technology transfer, user productivity, and DoD mission impact. The following example shows such an achievement.

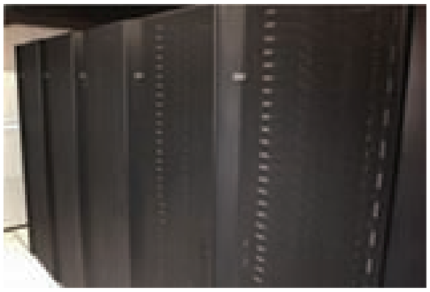
Scaling Security Code for Execution on Larger Linux Clusters

Problem

Data obfuscation is emerging as a key technology for enabling battle-space communication dominance. This technology allows friendly forces to send information securely without it being detected, decoded, or modified. It also provides friendly forces with the ability to detect, decode, and modify enemy communications. Air Force Research Laboratory, Information Directorate (AFRL/IF) researchers Chad Heitzenrater and Zenon Pryk have been conducting research in the area of data obfuscation with the goal of enhancing the performance of these DoD capabilities through the use of high performance computing. While the local Rome, NY, research site's ten-processor Linux cluster is invaluable for development purposes, it is limited in its ability to assist in solving larger and more realistic problems of DoD interest. A request to the HPCMP resulted in a large allocation on one of the HPCMP's premiere classified systems, Stryker, located at ARL. Unfortunately, neither Heitzenrater nor Pryk had access to the system because there is no available classified DREN connection at AFRL/IF. As a result, the AFRL researchers found themselves in a challenging situation with regard to continuing their HPC research activity.

Methodology

PET Team members Bill Yurcik and Paul Sotirelis met with the AFRL/IF researchers in August 2006 and developed a plan to assist Heitzenrater and Pryk in using Stryker. Yurcik arranged a meeting at ARL where Heitzenrater provided a brief introduction to his work and coordinated support from another member of the PET contracting team, Jim Fischer. Fischer was able to build the data obfuscation code and begin running jobs on Stryker. Throughout November and December 2006, an execution environment capable of running a comprehensive set of test cases was developed where nearly 64,000 CPU hours were utilized.



Users Supported

In addition to Heitzenrater and Pryk, other DoD personnel performing classified security-related processing may benefit from the capability to scale their code on larger Linux clusters.

DoD Impact

Larger and more DoD relevant data obfuscation problems may now be explored due to PET's support in enabling AFRL's access to its HPCMP allocation. The project in total has over 400,000 hours allocated to it and it is expected that now they will be able to utilize these hours as intended. Heitzenrater wrote, "*The work performed by the PET group has helped to fill a critical gap in a crucial technology area. Prior to their help, I was able only to test on local clusters, [and was] limited in scope to a maximum of 20 nodes. Preliminary data generated by the team has been analyzed, and has provided valuable input, which is being rolled into the final technical report for the High Performance Implementation of Data Obfuscation Technology program. Without this help I would not have been able to test this project to the scale it was designed to achieve, and without any other resources available, I would not be able to say nearly as much about the capability this program has achieved.*"

Goal 3: Acquire, deploy, operate and maintain a communications network that enables effective access to supercomputers and to distributed S&T/T&E computing environments

Defense Research & Engineering Network (DREN)

DREN was created to link high performance computing users and supercomputers, no matter where the person or resource is or with what Military Service they are associated (see Figure 16). From the beginning, DREN has acted as an enabler for the research, development, test and evaluation communities, the Missile Defense Agency (MDA), DoD Modeling & Simulation Office, Joint Forces Command (JFCOM), Defense Threat Reduction Agency, and others.

DREN enables MSRC to perform secure, large-scale, remote, mass-storage for HPC disaster recovery. Although it's always been highly desirable to do in-band (live on-line) mass storage transfers, it was in the "too hard to do" category. The challenge of transferring terabits of data daily between multiple centers was out of reach. Recently, a number of advances have made these types of data exchanges a reality. Access to the DREN backbone was expanded at each of the DoD major shared resource centers to optical carrier or OC-48 (approximately 2.4 gigabits per second). These centers are the first within the DoD to have massive wide-area network (WAN) access capabilities. Anticipating rapidly rising bandwidth demands, DREN revamped its backbone nationwide using new protocol architectures (multi-protocol label switching and internet protocol security tunnels) with jumbo frame enabled internet protocol which, in turn, permits high-end tuning of computational resources over thousands of miles for massive data transfers.

DREN is centrally funded for science and engineering users of DoD high performance computational resources. Other congressionally authorized groups (MDA, modeling & simulation, operational test and evaluation groups) not part of HPC line-item funding must offset service delivery point and security costs to access the DREN.

It is in the best interest of the DoD to continuously expand the pool of quality scientists and engineers working on high priority DoD problems. Potential new users often discover the availability of HPC resources through initial exposure to DREN. JFCOM in Suffolk, VA followed this pattern and eventually expanded into a joint, distributed, system-of-systems virtual communications concept for future real-time communications and network simulations. An advantage of DREN is that it makes high capacity bandwidth available to all computational resources wherever they may be. This approach makes it much easier to ensure optimal use of high performance computing assets and reduces the effective cost of these scarce resources.

Historically, we associated access to scarce and expensive resources with close proximity to major centers of civilization. Today, we have much more flexibility in the placement of new computational resources. That flexibility allows

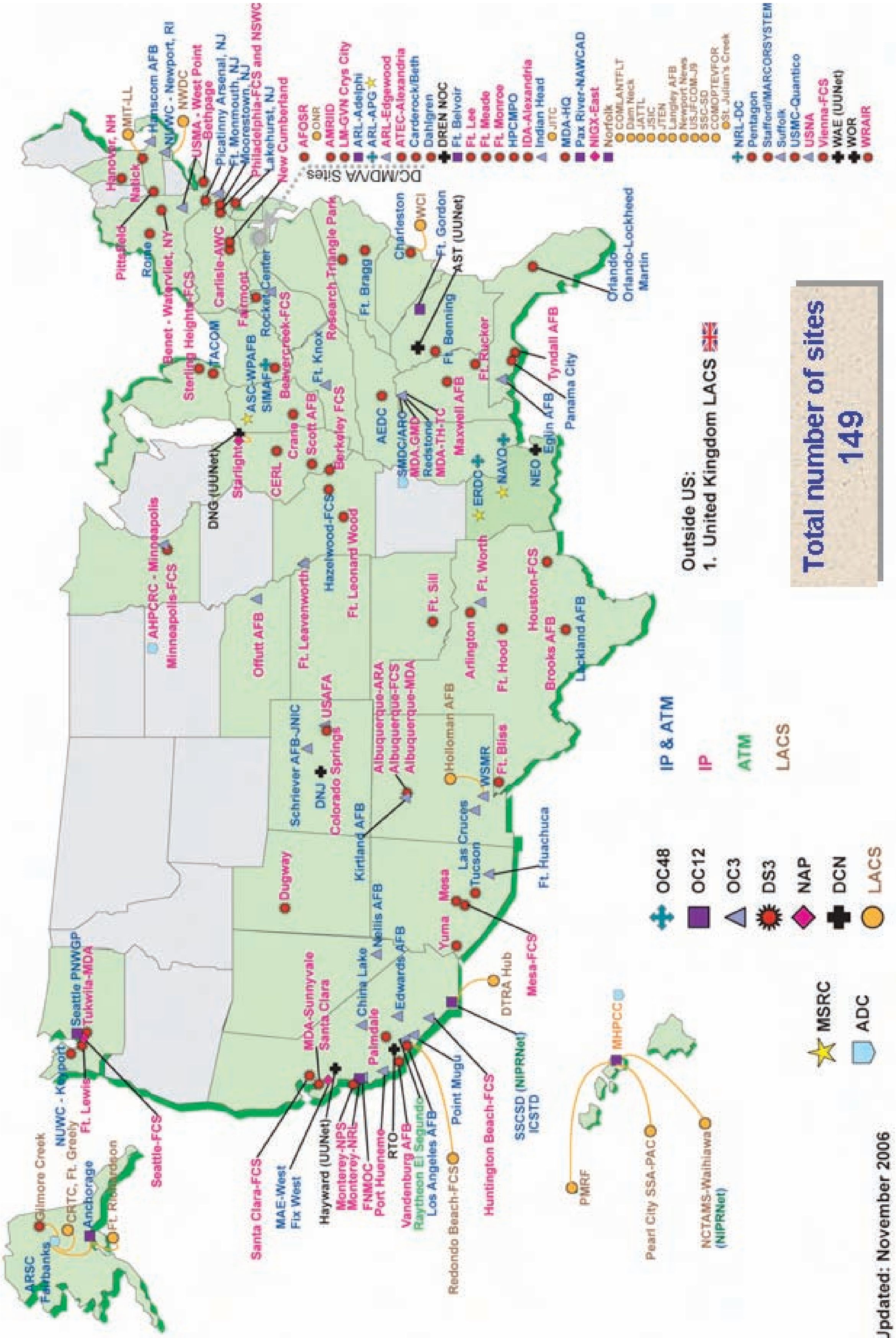


Figure 16. DREN connections, HPC centers and other network access points

growth of new skill and job opportunities to rural (Gulf Coast, Midwest, and Southwest) or remote (Alaska and Hawaii) labor markets that otherwise would be overlooked. High bandwidth WAN access allows the HPCMP to get resources very close to specialized real-time systems while expanding the pool of potential users working on DoD problems and keeps those resources extremely busy.

Goal 4: Promote collaborative relationships among the DoD computational science community, the national computational science community and minority serving institutions (MSIs)

Defense Research & Engineering Network (DREN)

As one of the three major areas of DoD's high performance computing modernization program, DREN draws from the high performance computing community most familiar with Defense supercomputing for technical and security advisory group members. DREN personnel also participate in the more generalized DoD networking and security communities within the Global Information Grid, through direct participation on DoD control boards and technical advisory councils, and by participating as a Tier 2 DoD Computer Emergency Response Team for hostile acts of intrusion and compromise.

DREN contributes to overall federal agency networking and security through the Large Scale Network (LSN) and Joint Engineering Team (JET). These groups maintain and extend US technological leadership in leading-edge network technologies and coordinate federal agency networking activities, operations, and plans represented by DoD DREN, Department of Energy, National Aeronautics and Space Administration, the National Science Foundation, Next Generation Internet, and Internet 2. The JET and LSN are part of the White House's Office of Science and Technology Policy Interagency Working Group.

DREN peers (exchanges network traffic) at international exchange points including Starlight in Chicago, and the Pacific Northwest Gigapop in Seattle, and at advanced exchanges including Next Generation Internet Exchanges East and West in Maryland and California. DREN actively participates in international science exchanges such as the Australian Meteorological and Oceanographic Society and Asian Pacific Advanced Networks projects.

User Productivity Enhancement and Technology Transfer (PET)

The EOTC functional area within PET is responsible for creating education opportunities targeted to undergraduate and graduate education, with emphases on MSIs, by sponsoring

summer intern programs and summer institutes. A goal is to create a workforce pipeline for the Department of Defense and the nation.

The Summer Intern program takes place in June, July, and August. The Summer 2006 Intern program was successful, and the student presentations are in the EOTC section on the PET Online Knowledge Center (OKC) (https://okc.erdc.hpc.mil). From these presentations we get the clear message that not only do the students gain valuable experience in a DoD laboratory environment, but the projects on which they work directly impact DoD research. A total of 34 summer interns from 26 universities were placed at six locations: ARL-Aberdeen, MD (7 interns); ERDC-Vicksburg, MS (8 interns); ASC-Wright-Patterson AFB, OH (14 interns); NRL-Stennis Space Center, MS (2 interns); NRL-Washington, DC (2 interns); and Air Force Weather Agency, Offutt AFB, NE (1 intern).

One of our primary efforts in attracting and preparing students at MSIs for the intern program is the summer institute program. The summer institute program is comprised of a two-week event at each of the four MSIs. Each institute introduces students to HPC and provides introductory instruction. In the Summer of 2006, PET sponsored institutes at Jackson State University, Florida International University, University of Hawaii, and Central State University. Fifty students attended the summer institutes where they collaborated with PET personnel from several functional areas, thus giving them a well-rounded experience, including the opportunity to present their work (see Figure 17).

Figure 17. Group of students that participated in the summer institute at Central State University

The Computational Science Workshop for Underrepresented Groups was held again in January 2006 on the campus of the University of Southern California (see Figure 18). This annual event, jointly supported by PET and other organizations, brings together students and faculty from MSIs for a week-long course on building a parallel computer, and on methods for solving problems in computational science.

In 2006, the following MSIs participated in PET education and technology transfer activities: Alabama A&M University, Central State University, Florida International University, Howard University, Jackson State University, University of Hawaii, North Carolina A&T University, University of Southern California, University of Texas at El Paso, and University of Texas at San Antonio.

Figure 18. Participants at the 2006 Computational Science Workshop for Underrepresented Groups

Goal 5: Continuously educate the RDT&E workforce with the knowledge needed to employ computational modeling effectively and efficiently

User Productivity Enhancement and Technology Transfer (PET)

The PET contracts offered 55 training events this past year, attended by 802 students, covering subjects ranging from code profiling and error estimators to user training on codes such as FLUENT, ABAQUS®, EnSight, and Xpatch®. See Table 4 for a sampling of courses given in FY 2006.

Many PET courses are captured on video and can be downloaded from the PET OKC (https://okc.erdc.hpc.mil) onto the users' desktops and viewed at their leisure.

While the OKC contains online training opportunities, it also is a repository of PET-developed technical reports, presentations, and points-of-contact. The computational fluid dynamics OKC front page (Figure 19) is typical of those for all the PET functional areas.

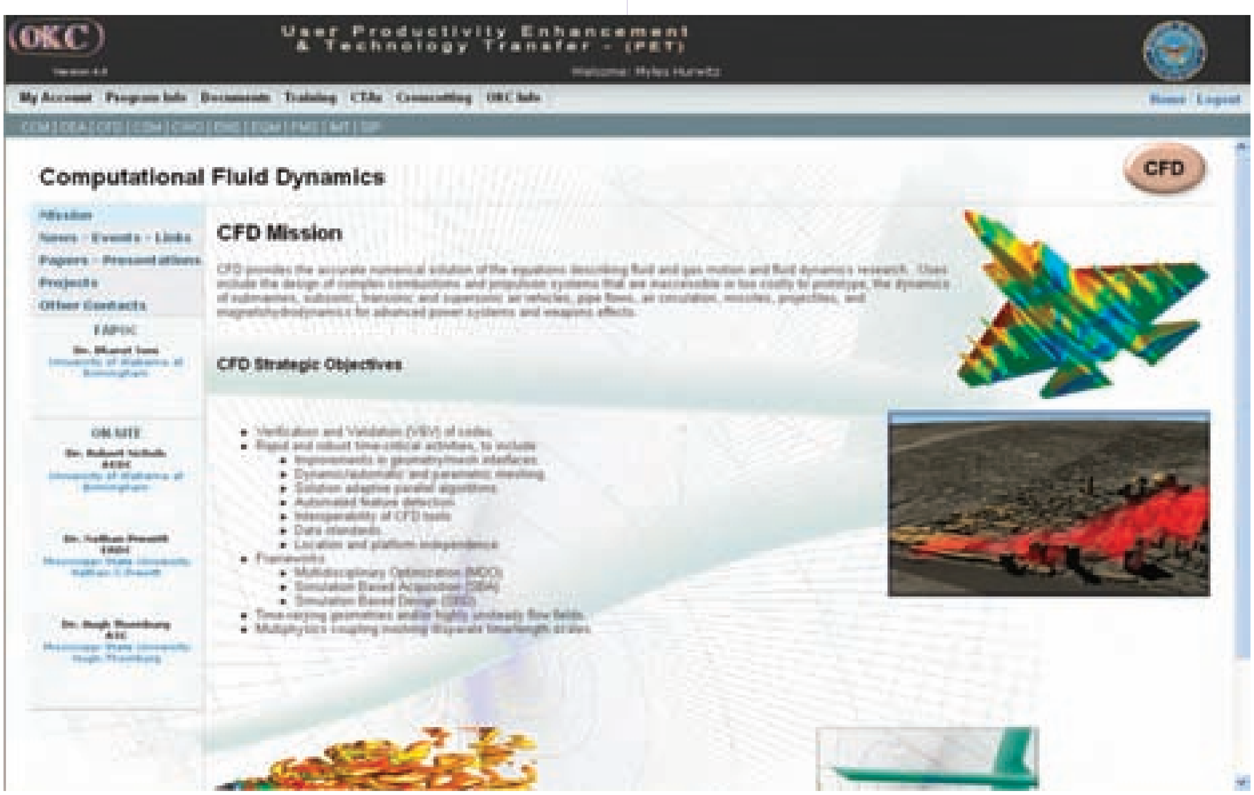


Figure 19. Sample of OKC webpage

Table 4. A Sampling of Training Courses Given in FY 2006

Course Title	Number of Attendees
ACES III Tutorial	4
ABAQUS®	17
Advanced EnSight	10
AIM Theory	8
ANSYS®	9
CFD Case Management Workshop	9
CFD Days	30
CFD Pre-Processing, Practice, Current Research, and Future Directions	36
CFD Tools and Technologies	16
Comprehensive VHDL Introduction	10
Contact in LS-DYNA®	7
Crosslight APSYS Training	8
CUBIT	9
Debugging Parallel Code N/A EMSF Workshop	21
FIELDVIEW	11
FLUENT Workshop	14
Force Field Lectures	50
HPC FPGA Programming	10
Insight Segmentation and Registration Toolkit Workshop (ITK)	18
Intermediate-Advanced EnSight	10
Introduction to Linux Cluster Computing; Rocks Cluster Management; and Introduction to Parallel Computing	27
Introduction to HPC Architectures and Parallel Computing and Workshop on Program Development for Computational Biology	15
Introduction to Parallel Programming with MPI	9
Introductory and Advanced MATLAB®	20
Introductory and Intermediate MATLAB®	19
Introductory EnSight	16
Lattice Heating in Quantum Well Laser Diodes	5
LS-DYNA®/ALE3D	11
Mass Conservation Issues in Flow and Transport Modeling	8
PanIX: Chemical Driving Force Module for HPC of Materials Behavior	20
Parallel GEMACS	13
Parallel Programming Using MatlabMPI	30
Performance Workshop – Bring Your Own Code	9
Python for Signal Processing	39
Scalable Quantum Chemistry Applications	40
Scientific Computing Using Python and Perl	15
Stars 3D	25
SUGGAR and gViz Training	19

Section 3

Financial Statements

Section 3
Financial Statements

FY 2006 Budget Resources

Financial Analysis

HPCMP funds are used for (1) capitalization, sustainment, and operations at the MSRCs; (2) annual capitalization for selected ADCs and DHPIs; (3) wide area network services for the DoD HPC community; (4) investments in human capital and key HPC software applications; and (5) expert HPC services from leading academic institutions. Figure 20 displays FY 2006 spending by component and Figure 21 shows FY 2007 planned spending by component.

We use multiple contracting officers in support of different efforts. Contracting officers at the General Services Administration support HPC equipment and services purchases, and contracting officers at various DoD installations support our service contracts. This structure is necessary because the program requires multiple contracts and contract types with an ongoing need to ensure that state-of-the-art technical capabilities are made available to DoD scientists and engineers in a timely manner. Contracts are a combination of firm fixed price, cost and/or indefinite delivery/indefinite quantity. All procurement awards are made for commercially available systems. Acquisitions are accomplished competitively to the fullest extent possible and encourage the inclusion of small, disadvantaged businesses and MSIs.

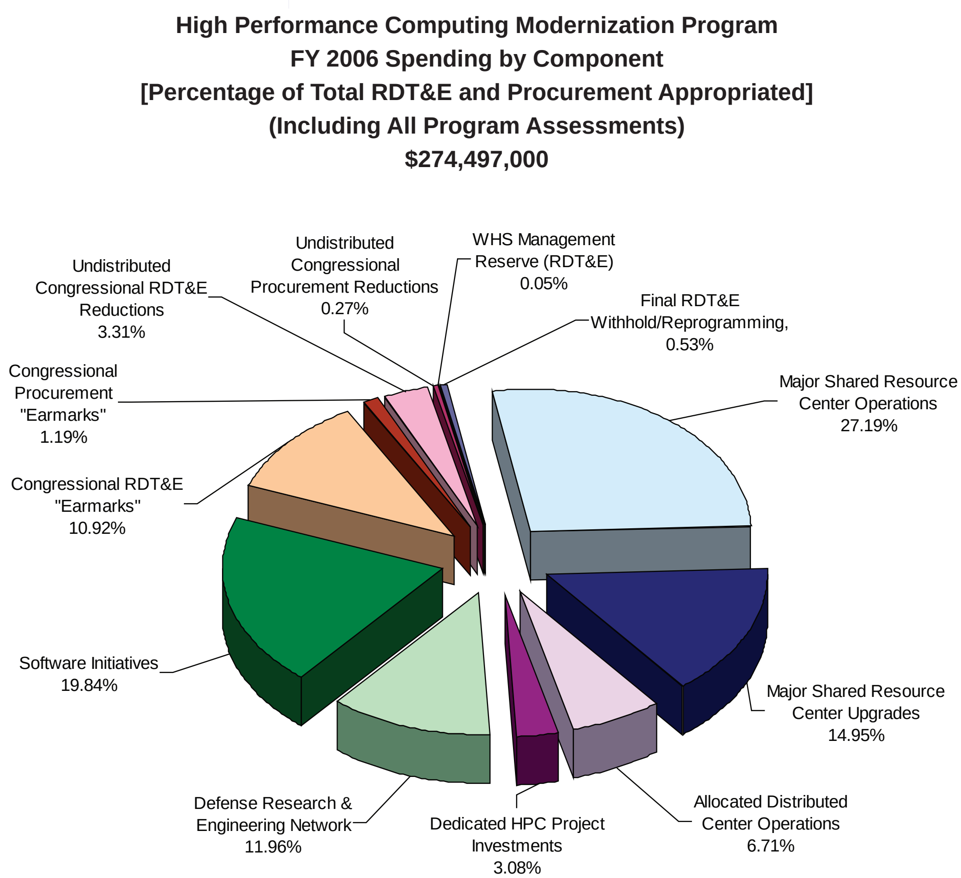


Figure 20. HPCMP FY 2006 spending by component

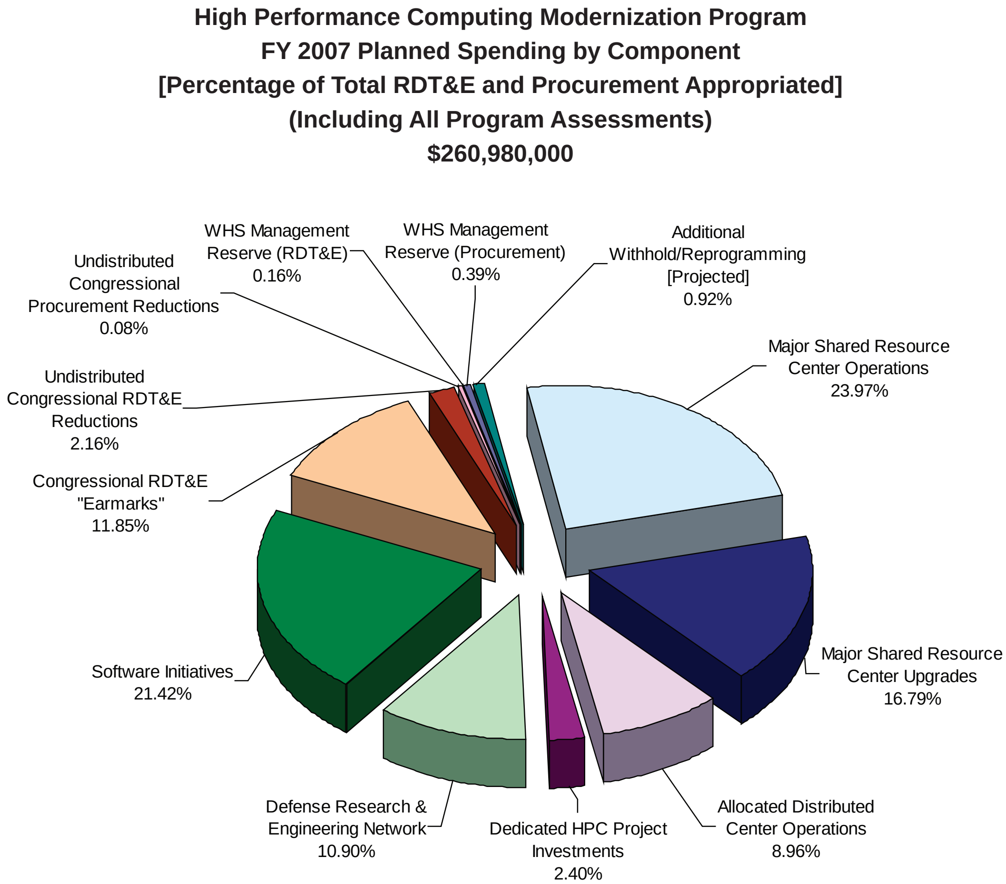


Figure 21. HPCMP FY 2007 planned spending by component

Obligations and Costs

Our Financial Manager conducts semi-annual reviews with each major component manager and major field activity to review actual cost performance against budgeted cost goals in a tailored work breakdown structure format with special attention on variance analysis. Significant variances are reported to our Program Director and corrective actions taken. We receive approximately $250,000,000 each year in funding appropriated for the DoD. Cash flow during 2006 is illustrated by the Cash Flow Statement on page 59.

We evaluate the effectiveness of each program component by measuring actual cost and schedule performance versus planned cost and schedule performance and through the measurement of actual outcomes versus planned outcomes. The MSRC contractors submit several reports regularly including a monthly and quarterly cost performance report and quarterly contract funds status report. Each contract specifies, as a deliverable, a work breakdown structure to facilitate the on-going review of smaller task components. Cost/schedule status reports are one of the primary tools used for oversight management of the MSRCs.

The balance sheet on page 58 shows the cumulative value of the program.

While the program has leveraged major cost performance improvements in computer technology since 1994, validated requirements have always exceeded the computing capability available to address those requirements. This occurs: 1) because the use of science-based models and simulations to answer research questions and solve engineering problems has grown dramatically; and 2) because fully funding the HPC requirement is unaffordable given the entire scope of activities the DoD budget must address. While fiscal resources do not fully meet the computational requirements of the science and technology and test and evaluation communities, the returns provided are substantial

with resources allocated to the highest priority projects. The FY 2006 Income Statement on page 60 shows these shortfalls.

Financial Trends

Except for minimal inflation adjustments, HPC budgets are essentially flat. We address urgent new requirements by adjusting priorities within the existing funding profile. We increased the overall capability of our HPC systems by about 80%, and added or upgraded systems at the ADCs. However, even with these increased capabilities, we are unable to meet validated DoD requirements. Development of the portfolios and institutes will continue. The DoD HPC user community will continue to be supported by the PET efforts. Our Software Protection Initiative will continue to mature. Figure 20 breaks out program-wide and planned spending during 2007.

The Income Statement on page 60 shows that currently we have a continuing deficit. The dollars we spend are not keeping up with the rapidly growing needs of the scientific community. Figure 22 displays spending by vendor in FY 2006 and Figure 23 shows planned spending by vendor in FY 2007.

Summary

We deploy, sustain, and upgrade commercially available high performance computing environments and networking services in support of DoD laboratories and test facilities. We have substantially improved the Department's computational capabilities with the objective of providing the DoD the technology to ensure dominance on the battlefield by the early fielding of the most advanced computing capability available.

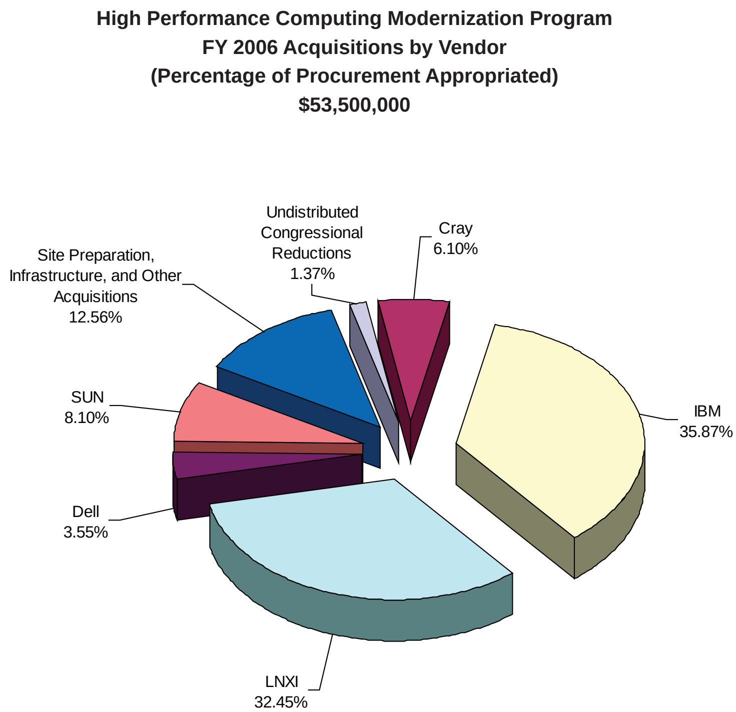


Figure 22. HPCMP FY 2006 acquisitions by vendor

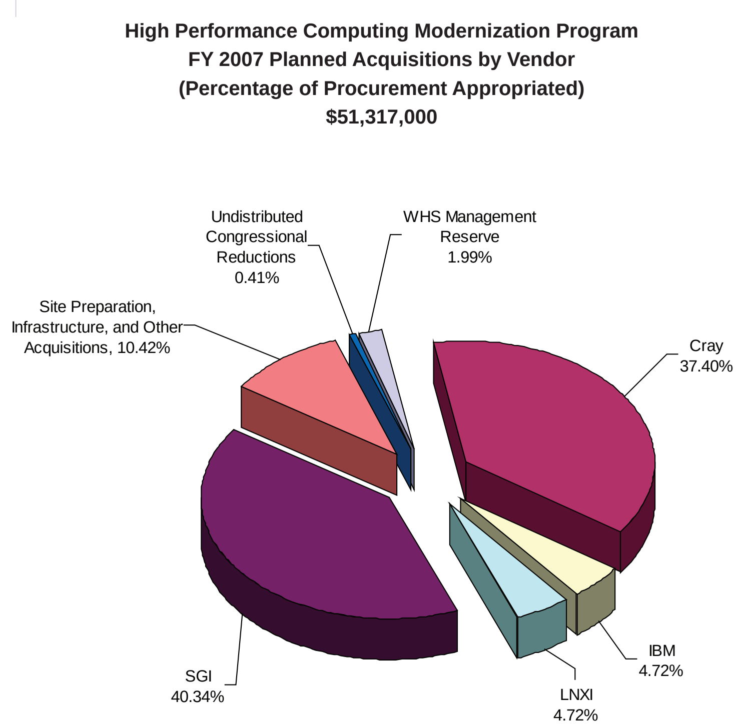


Figure 23. HPCMP FY 2007 acquisitions by vendor

High Performance Computing Modernization Program
Balance Sheet
As of March 30, 2007

Assets and Equity

Hardware		
Less: Depreciation	$1,085,107,999	
Fiscal Year 1994–2003:	$876,671,614	$144,334,956
Fiscal Year 2004:	$34,101,429	
Fiscal Year 2005:	$22,461,857	
Fiscal Year 2006:	$7,538,143	
Fiscal Year 2007:	$0	
Software (1)		
Less: Depreciation	$260,707,356	
Fiscal Year 1994–2001:	$130,715,508	
Fiscal Year 2002:	$19,282,037	
Fiscal Year 2003:	$13,789,787	
Fiscal Year 2004:	$9,059,434	
Fiscal Year 2005:	$6,828,937	
Fiscal Year 2006:	$2,260,489	
Fiscal Year 2007:	$0	$78,771,164
Manpower Contracts (2 & 3)		
Software Development		
Exercised Contract Value	$23,204,057	
Less: Value Consumed Remaining Exercised Value	$20,736,559	$2,467,498
Maintenance Contracts (2 & 3)		
Hardware Maintenance		
Fiscal Year 2007:	$14,506,216	
Software Maintenance		
Fiscal Year 2007:	$1,937,007	
Less: Value Consumed		
Hardware Maintenance		
Fiscal Year 2007:	$11,062,877	
Software Maintenance		
Fiscal Year 2007:	$1,465,558	$3,914,788
Intellectual/Operations		
Government Labor		
Fiscal Year 2007:	$23,835,734	
Contract Labor		
Fiscal Year 2007:	$91,821,495	
Less: Value Consumed		
Government Labor		
Fiscal Year 2007:	$18,480,506	
Contract Labor		
Fiscal Year 2007:	$73,494,677	$23,682,046
Facilities		
Fiscal Year 2007:	$45,892,491	
Less: Value Consumed		
Fiscal Year 2007:	$33,720,863	$12,171,628
	Total Assets	**$265,342,080**

Liabilities

Uncompleted Software Development	$2,467,498	
Maintenance Contract Liabilities		
Hardware		
Fiscal Year 2007:	$3,443,339	
Software		
Fiscal Year 2007:	$471,449	
Intellectual/Facilities Expense		
Government Labor		
Fiscal Year 2007:	$5,355,228	
Contract Labor		
Fiscal Year 2007:	$18,326,818	
Facilities		
Fiscal Year 2007:	$12,171,628	
Total Liabilities	**$42,235,960**	
	Program Equity	**$233,106,120**
	Total Liability and Program Equity	**$265,342,080**

(1) Research, Development and Engineering funding used to develop inventory software.

(2) Office of Management and Budget Circular A-11, Section 300 - Planning, Budgeting, Acquisition, and Management of Capital Assets (Paragraph 300.4), defines capital assets as land, structures, equipment, intellectual property (e.g., software), and information technology (including IT service contracts) that are used by the Federal government and have an estimated useful life of two years or more. Therefore, manpower is treated as a capital asset.

(3) Small consumable items such as computer tapes and supplies are considered as expense items and not carried as inventory items.

High Performance Computing Modernization Program
Cash Flow Statement
October 1, 2005 — September 30, 2006

	Fiscal Year 2006
Revenue	
Research, Development and Engineering Funding	
President's Budget	$189,747,000
Congressional Funding	$31,250,000
Department of Defense Reprogramming - In	$0
(Less Congressional Undistributed Reductions)	($9,077,000)
(Less Unreleased Obligation Authority)	($1,588,500)
Net Research, Development and Engineering Funding	**$210,331,500**
Procurement Funding	
President's Budget	$49,501,000
Congressional Funding	$4,000,000
Department of Defense Reprogramming - In	$0
(Less Department of Defense Reprogramming - Out)	($734,000)
Net Procurement Funding	**$52,767,000**
Net Revenue	**$263,098,500**
Investments	
Major Shared Resource Center Upgrades	$41,037,722
Allocated Distributed Center Upgrades/Dedicated HPC Project Investments	$11,729,278
Software Development	$21,474,645
Expense	
Major Shared Resource Center Operations	$82,466,831
Allocated Distributed Center Operations	$40,567,758
Defense Research & Engineering Network	$32,818,574
Software Initiatives	$33,003,692
Net Expense	**$263,098,500**
Balance (As of September 30, 2006)	**$0**

High Performance Computing Modernization Program
Income Statement
October 1, 2005 — September 30, 2006

	Fiscal Year 2006
Income	
Research, Development and Engineering Funding	
Major Shared Resource Center Operations	$82,466,831
Allocated Distributed Center Operations	$40,567,758
Defense Research & Engineering Network	$32,818,574
Software Initiatives	$54,478,337
Procurement Funding	
Major Shared Resource Center Upgrades	$41,037,722
Allocated Distributed Center Upgrades	$11,729,278
Defense Research & Engineering Network	$0
Software Initiatives	$0
Total Income	**$263,098,500**
Expense[1]	
Research, Development and Engineering Funding	
Major Shared Resource Center Operations	$82,466,831
Allocated Distributed Center Operations	$40,567,758
Defense Research & Engineering Network	$32,818,574
Software Initiatives[2]	$33,033,692
Depreciation of Capital Assets	
Hardware (Depreciated based upon a 48-month life-cycle)[3]	$55,384,000
Software (Depreciated based upon a 60-month life-cycle)[4]	$20,066,079
Total Expense[5]	**$264,306,934**
Balance (As of September 30, 2006)	**($1,208,434)**

Note 1: Expenses include travel; supplies; government and contractor salaries and training; maintenance of hardware and software; studies and analysis; annual operations investments; communications, utilities, facilities lease, and facilities maintenance.

Note 2: Software initiatives are separated into two distinct categories—expenses associated with research and development, management, education/training, and expert services; and capitol assets resulting from developed software.

Note 3: Depreciation for HPC hardware is calculated using a 48-month straight-line depreciation method. Current HPC technology development results in predictable obsolescence. Generally after 48 months of use, HPC systems are retired with little or no residual value. Fiscal year 2006 depreciation includes the 12-month value calculated for all systems in the inventory between October 1, 2005 through September 30, 2006.

Note 4: Depreciation for HPC software is calculated using a 60-month straight-line depreciation method. A period of 60 months is used because it is the typical life cycle of HPC software before significant modifications are required. Fiscal year 2006 depreciation includes the 12-month value calculated for all software in the inventory between October 1, 2005 through September 30, 2006.

Note 5: Annual program investments in system hardware have not been made at levels sufficient to maintain stable equipment inventories. For several years depreciated values have not been offset by new assets.

Acronyms

Acronyms

2-D	two-dimensional
3-D	three-dimensional
ADCs	allocated distributed centers
AFB	Air Force Base
AFRL/IF	Air Force Research Laboratory, Information Directorate
AFRL/SNHE	Air Force Research Laboratory, Sensors Directorate, Electromagnetic Scattering Branch
AHPCRC	Army High Performance Computing Research Center
ARL	Army Research Laboratory
ARSC	Arctic Region Supercomputing Center
ASC	Aeronautical Systems Center
ASK	Armor Survivability Kit
BEI	Battlespace Environments Institute
BHSAI	Biotechnology HPC Software Applications Institute for Force Health Protection
C4ISR	command, control, communications, computers, intelligence, surveillance and reconnaissance
CAP	capability applications projects
CBoD	Centers Board of Directors
CCM	computational chemistry, biology, and materials science
CDLT	collaborative and distance learning technologies
CE	computational environment
CEA	computation electromagnetics and acoustics
CERDEC	Command Electronics Research, Development and Engineering Center
CFD	computational fluid dynamics
CPU	central processing unit
CREATE	Computational Research and Engineering Acquisition Tools and Environments
CSM	computational structural mechanics
CST	collaborative simulation and testing
CTAs	computational technology areas
CWO	climate/weather/ocean modeling and simulation
DARPA	Defense Advanced Research Projects Agency
DHPIs	Dedicated HPC Project Investments
DIOT	Distributed Implementation and Operations Team

DoD	Department of Defense
DOE	Department of Energy
DREN	Defense Research and Engineering Network
DPG	Dugway Proving Ground
ED&PMB	Engineering Design and Process Management Board
ESMF	Earth Systems Modeling Framework
ENS	electronics, networking, and systems/C4I
EOTC	education, outreach, and training coordination
ERDC	Engineer Research and Development Center (USACE)
EQM	environmental quality modeling and simulation
ET	enabling technologies
FLOPS	FLoating-point OPerations per Second
FMS	forces modeling and simulation
FY	fiscal year
GAO	Government Accountability Office
GFs	gigaFLOPS
GMTI	ground moving-target indication
HI-ARMS	HPC Institute for Advanced Rotorcraft Modeling and Simulation
HPC	high performance computing or high performance computer
HPCMP	High Performance Computing Modernization Program
HPCS	DARPA's High Productivity Computing Systems
IED	Improvised explosive device
IHAAA	Institute for HPC Applications to Air Armament
IM	Insensitive Munitions
IMT	integrated modeling and test environments
IMTPS	Institute for Maneuverability and Terrain Physics Simulation
ISSA	HPC Software Applications Institute for Space Situational Awareness
JFCOM	Joint Forces Command
JET	Joint Engineering Team
LSN	large scale network
MDA	Missile Defense Agency
MFT	multiphase flow target response
MHPCC	Maui High Performance Computing Center
MiniSAR	Miniaturized Synthetic Aperture Radar
MIT	Massachusetts Institute of Technology
MSIs	Minority Serving Institutions
MSRCs	major shared resource centers

NASA	National Aeronautics and Space Administration
NAVO	Naval Oceanographic Office
NUWC	Naval Undersea Warfare Center
OKC	Online Knowledge Center
OneSAF	One Semi-Automated Forces
OOS	One Semi-Automated Forces (OneSAF) Objective System (OOS)
OSD	Office of Secretary of Defense
PCID	physically-constrained iterative deconvolution
PET	User Productivity Enhancement and Technology Transfer
PEUO	physics-based environment for urban operations
RDT&E	research, development, test, and evaluation
ROI	return-on-investment
S&T	science and technology
SAR	synthetic aperture radar
SAS	Software Applications Support
SIP	signal/image processing
SMDC	Army Space and Missile Defense Command
SSA	space situational awareness
SSCSD	Space and Naval Warfare Systems Center, San Diego
SSN	Space Surveillance Network
STAP	space-time adaptive processing
T&E	test and evaluation
TI	technology insertion
US	United States
USACE	US Army Corps of Engineers
VED	virtual electromagentics design
WAN	wide area network

2006

High Performance Computing Modernization Program Office

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